AN INVESTIGATION OF SYNOPTIC AND ASSOCIATED MESOSCALE PATTERNS LEADING TO SIGNIFICANT WEATHER DAYS AT McMURDO STATION, ANTARCTICA

Raymond H. Godin

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN INVESTIGATION OF SYNOPTIC AND ASSOCIATED MESOSCALE PATTERNS LEADING TO SIGNIFICANT WEATHER DAYS AT McMURDO STATION, ANTARCTICA

by

Raymond H. Godin

June 1977

Thesis Advisor: R. J. Renard

Approved for public release; distribution unlimited.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) An Investigation of Synoptic and Associated Mesoscale Patterns Leading to Significant Weather Days at McMurdo Station, Antarctica		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; June 1977
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Raymond H. Godin		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE June 1977
		13. NUMBER OF PAGES 114
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Satellite observations; DMSP satellite; NOAA satellite; Antarctic; synoptic analysis; mesoscale analysis; polar meteorology; McMurdo, Antarctica.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Defense Meteorological Satellite Program (DMSP) and National Oceanic and Atmospheric Administration (NOAA) satellite imagery are used to supplement conventional radiosonde and aircraft data in an investigation of synoptic and associated mesoscale weather patterns leading to significant weather at McMurdo Station and the adjacent Ross Ice Shelf, Antarctica. Three case studies, 8-11 January 1976, 22-25 December 1975, and 11-13 October 1973, are analyzed, with concentration on the 700 and 400 mb

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
(Page 1) S/N 0102-014-6601 |

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

levels. Meridional advection associated with ridging over the Ross Ice Shelf and/or the polar plateau serves as the moisture intrusion mechanism for significant weather in each case study. Mesoscale features about the McMurdo area serve as both triggering and blocking mechanisms preceding the significant weather events. Katabatic winds associated with glacial valley warming, originating from the polar plateau near McMurdo, are detected on DMSP infrared satellite imagery. Comparisons between Fleet Numerical Weather Central's 700 mb analyses with those of the author demonstrate the inadequacy of satellite-void analyses over the sparse data ice/snow covered south polar region.

Approved for public release; distribution unlimited.

An Investigation of Synoptic and Associated Mesoscale Patterns Leading to Significant Weather Days at McMurdo Station, Antarctica

by

Raymond H. Godin
Lieutenant, United States Naval Reserve
B.S., Lowell Technological Institute, 1971

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN METEOROLOGY

from the

NAVAL POSTGRADUATE SCHOOL
June 1977

ABSTRACT

Defense Meteorological Satellite Program (DMSP) and National Oceanic and Atmospheric Administration (NOAA) satellite imagery are used to supplement conventional radiosonde and aircraft data in an investigation of synoptic and associated mesoscale weather patterns leading to significant weather at McMurdo Station and the adjacent Ross Ice Shelf, Antarctica. Three case studies, 8-11 January 1976, 22-25 December 1975, and 11-13 October 1973, are analyzed, with concentration on the 700 and 400 mb levels. Meridional advection associated with ridging over the Ross Ice Shelf and/or the polar plateau serves as the moisture intrusion mechanism for significant weather in each case study. Mesoscale features about the McMurdo area serve as both triggering and blocking mechanisms preceding the significant weather events. Katabatic winds associated with glacial valley warming, originating from the polar plateau near McMurdo, are detected on DMSP infrared satellite imagery. Comparisons between Fleet Numerical Weather Central's 700 mb analyses with those of the author demonstrate the inadequacy of satellite-void analyses over the sparse data ice/snow covered south polar region.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

The author would like to express his appreciation to Dr. Robert J. Renard, whose expert guidance, patient assistance and support were instrumental in the completion of the study.

Special thanks are extended to Mr. K. Rabe and Mr. R. Fett, Naval Environmental Prediction Research Facility for their assistance in providing DMSP satellite imagery used in this thesis, and to Mr. M. McDermet and the personnel assigned to the Meteorology Laboratory, NPS, for their attention to the technical needs of the author.

Appreciation is also extended to the Naval Weather Service Detachment, Asheville, North Carolina for furnishing observations and analyses used in the preparation of this study and to Dr. R. Elsberry, NPS, for his comments and suggestions on the text.

Finally, to my wife, Marie, my sincere gratitude for her hours of assistance in the completion of the final manuscript.

I. INTRODUCTION

The United States Navy has the responsibility of providing logistic support for the scientific research efforts sponsored by the National Science Foundation in Antarctica. The operational efficiency and safety required of such an endeavor necessitates the availability of timely and accurate weather forecasts (Renard, 1975).

Although weather satellite observations have existed for some 17 years, it is only in the past 10 years that such information has been available to the Antarctic weather group on an operational basis. But until recently, poor cloud/polar ice cap contrast due to low imagery resolution has greatly limited researchers (Streten and Troup, 1973) and operational meteorologists alike in the development and application of satellite interpretation techniques to latitudes poleward of 65 deg.

The development of high resolution infrared (IR) and visual (VIS) satellite sensor systems such as those aboard the recent National Oceanic and Atmospheric Administration (NOAA) and Defense Meteorological Satellite Program (DMSP) satellites has enhanced the identification of synoptic and mesoscale weather processes over the polar ice cap. This thesis study concentrates on an investigation of the synoptic weather sequences that lead to significant weather at McMurdo Station, Antarctica, utilizing conventional (surface and rawinsonde) aircraft data, and satellite (NOAA/DMSP) observations.

II. OBJECTIVES

The objectives of this thesis are (1) to identify the synoptic-scale and associated mesoscale weather patterns leading to significant weather days at McMurdo Station, Antarctica and (2) to demonstrate the interrelationship of conventional data and satellite imagery in the description of such phenomena.

To accomplish these objectives, a limited number of case studies were analyzed in some detail. A table was compiled listing the significant weather days and type of weather observed at McMurdo during the austral spring and summer period from about middle September through middle March, from September 1971 through January 1977. (See Appendix A.) For the purpose of this study, a significant weather day is one in which McMurdo surface observations report a reduction in visibility to one mile or less.

III. AREA AND PERIOD OF STUDY

The area of study is outlined by the rectangle superimposed on the polar stereographic Southern Hemisphere map in Fig. 1. The area analyzed in the case studies encompasses those regions where the major synoptic features affect the Ross Ice Shelf area, and especially McMurdo, Antarctica.

Because of the convergence of longitudinal meridians to 90S, a linear grid direction scheme exists in order to avoid confusion and to facilitate navigation in the polar latitudes (Fig. 1). The grid is centered at the geographical South Pole with grid north directed northward along the Greenwich prime meridian, 0 deg; grid south along the 180th meridian; grid east along 90 deg. E; and grid west along 90 deg W. As an example, a geographic wind direction of 360 deg. at 80S lat 135W long, may be stated as 225 deg grid.

Two of the case studies (8-11 January 1976 and 22-25 December 1975) were chosen from the period when 700 mb Fleet Numerical Weather Central (FNWC) analyses are available. The third case study involves katabatic wind observations (11-13 October 1973) with which the author had first-hand experience as an operational weather forecaster at McMurdo Station.

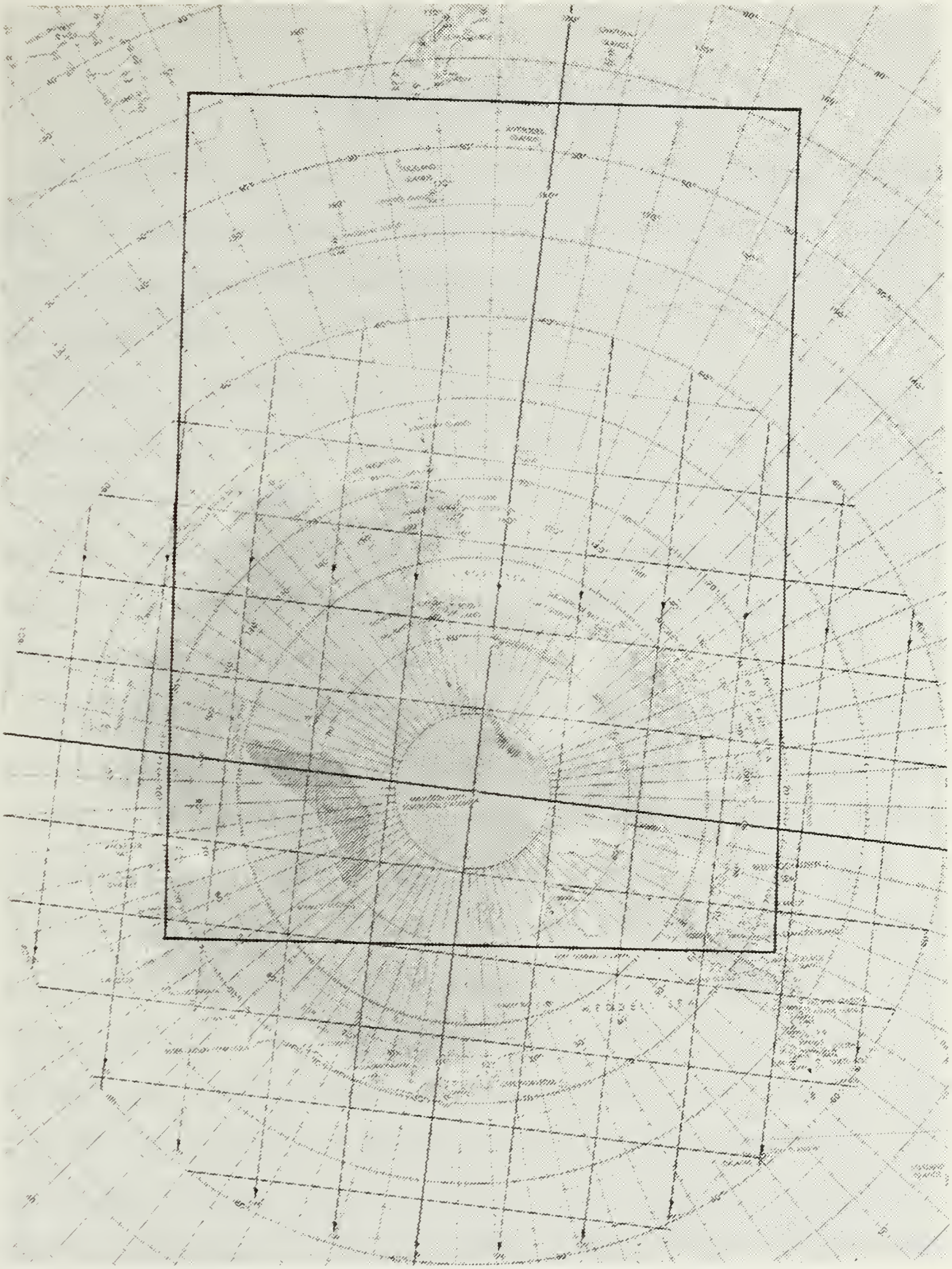


Figure 1. Southern Hemisphere polar-stereographic map with outline of area analyzed and grid directions.

IV. PHYSICAL FEATURES/TOPOGRAPHY

Over 90% of the Antarctic continent is covered by perennial ice and snow. The remaining exposed surfaces are made up of mountain outcrops on the boundaries of the polar plateau and terrain in the vicinity of some coastal areas.

Observing a topographic map (Fig. 2) it is noted that in the center of East Antarctica lies the apex of an enormous ice dome, approximately 15,000 feet high, located in the vicinity of the Pole of Inaccessibility (82S 55E). Away from this area, elevations decrease gradually and very slowly in all directions to an altitude of 6000 to 8000 feet about 150 to 200 nmi from the Antarctic coastline.

To the east and northeast (or grid southwest) of this ice dome lies the most prominent physical feature of East Antarctica, the Trans-Antarctic Mountain Range which forms the eastern boundary of the polar plateau. The Trans-Antarctic Mountain Range extends from the northeast tip of the Admiralty Range near 72S 170E to the Royal Society Range (southwest of McMurdo) and thence to the Queen Maud Range in the extreme south near the 85th parallel. The Range rises steeply from the periphery of the Continent and is approximately 100 miles wide having many peaks in excess of 14,000 feet southwest of McMurdo in its southernmost extension. Cutting through the Trans-Antarctic Mountain Range from the plateau are numerous steep glacial valleys descending from the 6000 to 8000 ft ice cap to the 2-300 ft Ross Ice Shelf.

McMurdo Station is located in the southernmost tip of Ross Island (Fig. 3), which is located about 40 miles east of the Victoria Land Coast

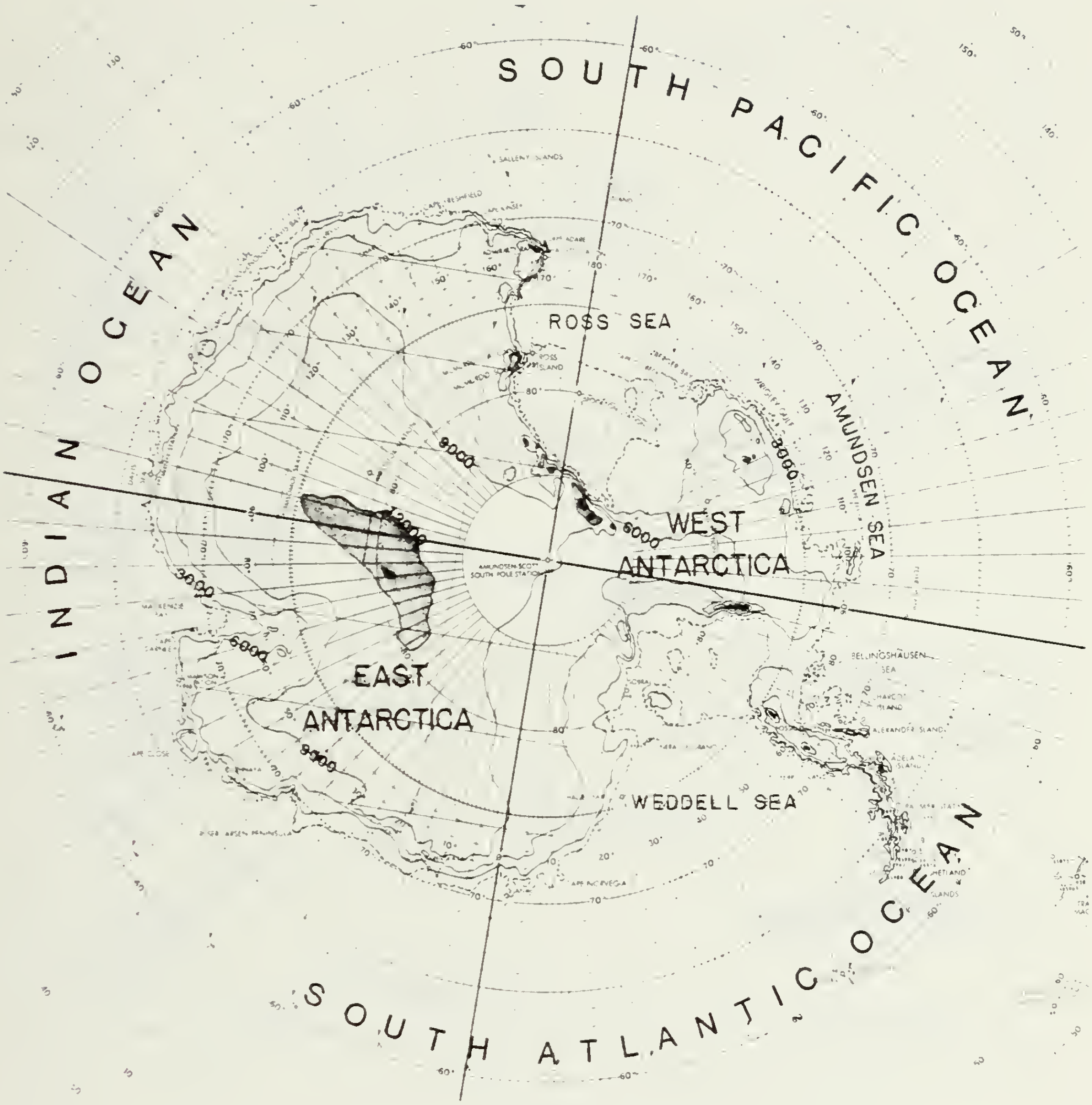


Figure 2. Antarctic topographic map.

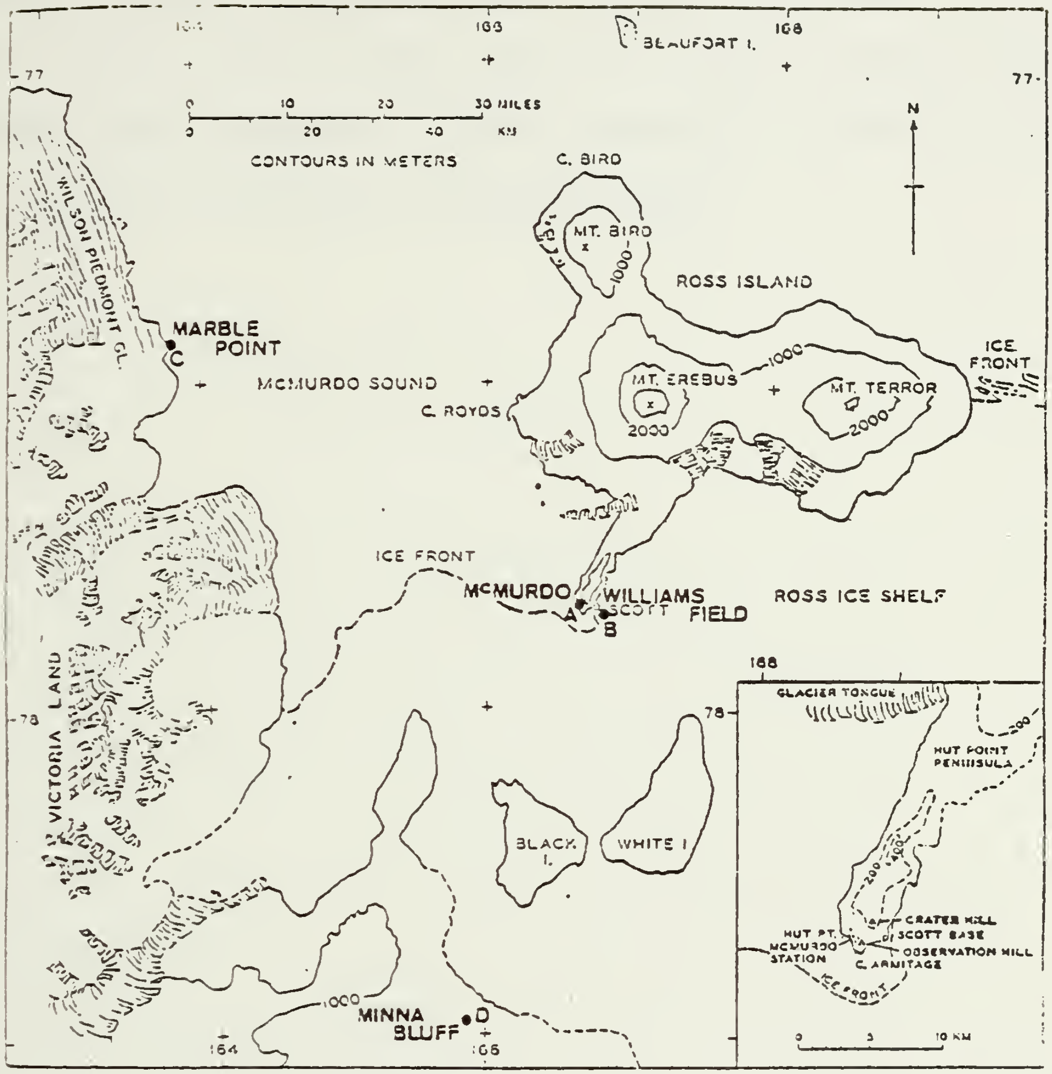


Figure 3. Ross Island area topographic map.

on the western boundary of the Ross Sea and along the edge of the Ross Ice Shelf. Ross Island contains an active volcano, Mount Erebus (elev. 14000 ft), and two other mountains, Mount Terror and Mount Bird. South of McMurdo are White and Black Islands, and Minna Bluff which is an extension of Mount Discovery (elev. 8000 ft) in the Royal Society Range. Extending south through east of these features lies the relatively flat Ross Ice Shelf, stretching out hundreds of miles.

V. DATA/ANALYSES

A. SURFACE/UPPER AIR OBSERVATIONS

Meteorologists pursuing research or performing operational tasks in the polar region are acutely aware of the paucity of data. Antarctica is no exception. Spread over an area of roughly 5,500,000 square miles are approximately 30 observation stations, of which less than half take upper-air soundings and some only once a day. Table I lists these stations with a roster of available observations. Fig. 4 shows their locations.

Of the Antarctic stations with upper-air capabilities only four, McMurdo (NZCM), Vostok, Dumont D'Urville, and Amundsen-Scott (South Pole) are located in the area covered by analyses in the case studies. No surface station data were available over West Antarctica from 90W to 180 during the periods of study. Even at stations with rawinsonde capability, soundings are often aborted during periods of high surface winds or missing altogether.

B. AIRCRAFT REPORTS (AIREPS)

The navigation fixes reported by U. S. Navy LC-130 aircraft are the result of either the inertial navigational system (INS) with an accuracy of $\pm$ 4 nmi or celestial fixes, accuracy of $\pm$ 10 nmi. Wind directions are observed through doppler radar or INS, both of which have accuracies of $\pm$ 5 deg direction and $\pm$ 5 kt wind speed. The temperatures from an exterior probe on the aircraft have a corrected accuracy of $\pm$ 2°C. Navy aircraft flying between New Zealand and McMurdo report at predesignated

TABLE I. ANTARCTIC WEATHER REPORTING STATIONS

WMO BLOCK/ STATION NUMBER	STATION NAME	LATITUDE	LONG.	SFC. ELEV. METERS	COUNTRY	SYNOPS	AVIATION HOURLYS (Summer only)	UPPER AIR 00Z	UPPER AIR 12Z (Summer only)
89586	Arturo Prat	62.30S	59.41W	5	Chile	X			
85988	Bernardo O'Higgins	63.19S	57.54W	10	Chile	X			
88952	Argentine Is.	65.15S	64.16W	10	U.K.	X		X	
88958	Adalaide Is.	67.46S	68.55W	25	U.K.	X(1800 ONLY)			
88963	Base Esperanza	62.24S	56.59W	8	Argentina	X			
88967	General Belgrano	77.58S	38.48W	31	Argentina	X			
88968	Islas Orcadeas	60.44S	44.44W	5	Argentina	X			
88970	Base Matienzo	64.58S	60.03W	32	Argentina	X			
89001	SANAE	70.19S	2.22W	52	So. Africa	X			
89009	Amundsen-Scott	90.00S	0.00	2800	USA	X	X	X	X
89022	Halley Bay	75.30S	26.39W	31	U.K.	X			
89050	Bellingshausen	62.12S	58.56W	16	USSR	X		X	
89051	Petrel NAS	63.28S	56.17W	18	Argentina	X			
89055	Vice Comodoro Mar	64.14S	56.43W	198	Argentina	X			
89061	Palmer	64.46S	64.05W	8	USA	none			
89083	Siple	75.55S	83.55W	1280	USA	X	X		
89125	Byrd Camp	80.01S	119.32W	1530	USA	X	X	X	X
89512	Novolazarevskaya	70.46S	11.50E	102	USSR	X		X	
89532	Syowa	69.00S	39.35E	15	Japan	X		X	
89542	Molodezhnya	67.40S	45.51E	40	USSR	X		X	X
89571	Davis	68.35S	77.59E	15	Australia	X		X	X
89592	Mirny	66.33S	93.01E	35	USSR	X		X	X
89606	Vostok	78.27S	106.54E	3420	USSR	X		X	
89611	Casey	66.16S	110.38E	11	Australia	X		X	X
89657	Leningradskaya	69.30S	159.23E	30	USSR	X			
89663	Lake Vanda	77.32S	161.38E	138	New Zealand	X			
89664	McMurdo	77.53S	166.44E	24	USA	X		X	X
89665	Scott Base	77.51S	166.45E	16	New Zealand	X not transmitted			
89674	Williams Field	77.52S	166.58E	15	USA		X		
95002	Dumont d'Urville	66.40S	140.01E	41	France	X		X	
96986	Mawson	67.36S	62.53E	14	Australia	X		X	X

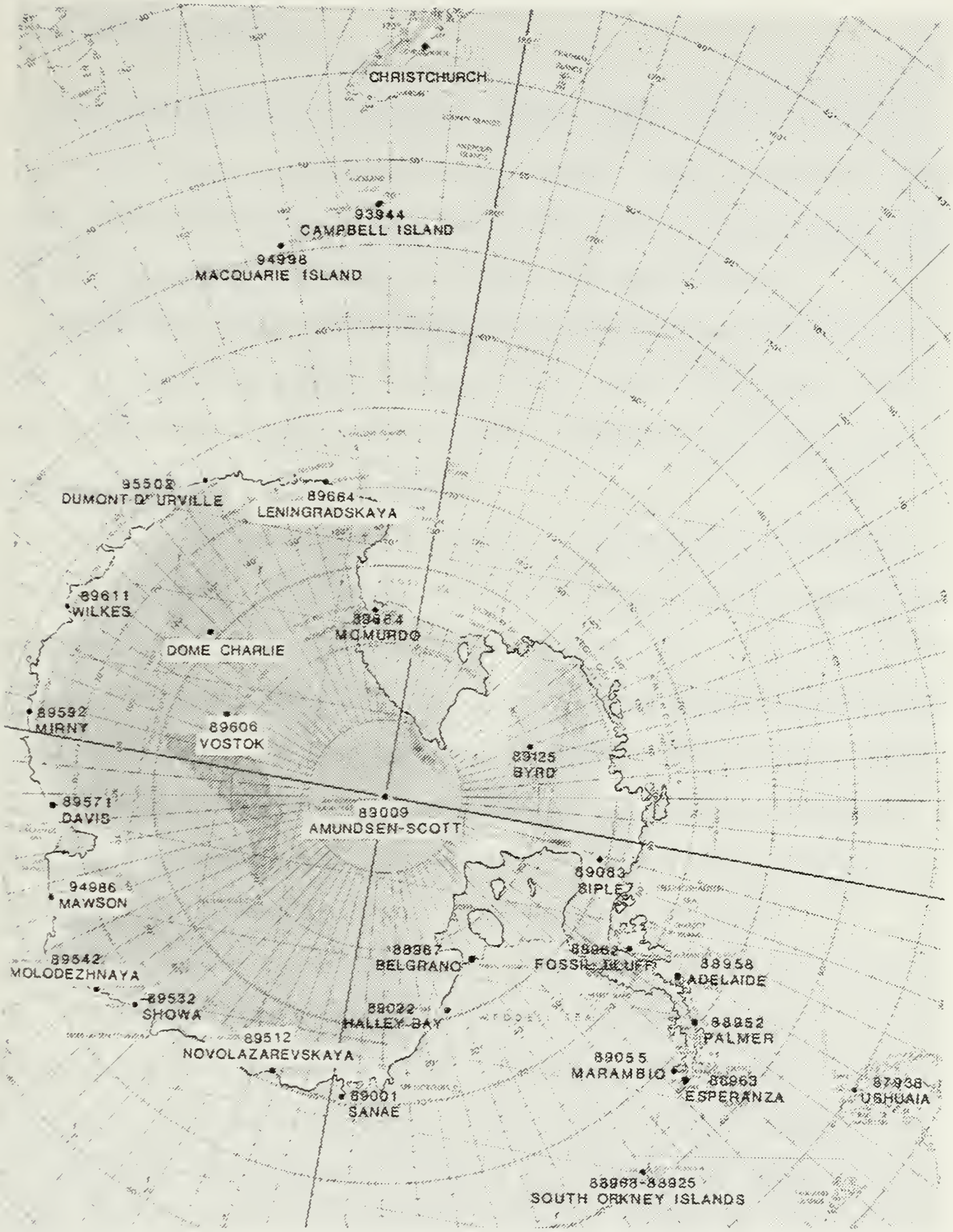


Figure 4. Map of Antarctica showing distribution of stations.

two and one-half deg lat locations and at specific points on intracontinental Antarctic flights.

C. DEFENSE METEOROLOGICAL SATELLITE PROGRAM (DMSP) SATELLITE IMAGERY

The DMSP imagery were obtained from the DMSP interim national archive at the Space Science and Engineering Center, University of Wisconsin where DMSP data extending back to March of 1973 have been archived.

The DOD DMSP Block V satellites (1970-1975) were launched into a polar, sun-synchronous orbit, with an orbital period of 102 min. The primary sensor is a four-channel scanning radiometer with two counter-rotating Cassegrain optical systems.

The visual (H) and thermal infrared, (I) channel type imagery were used in this study. The imagery are in the form of positive transparencies which have been produced by ground equipment on a scale of 1 to 15 million. The images have been corrected to remove apparent compression at the strip edges. Because the sensor's field of view is not constant across a swath, there is a resultant loss of resolution at the edges. The H and I data were usually paired and are geometrically coherent at the sensor, in transmission, and in the resultant processing.

Both the visual, H, and infrared, I, channels have a two nmi resolution. The visual H data channel senses wavelengths in the 0.4μ to 1.0μ range, with a peak response at 0.8μ. Processed film density is linearly proportional to scene reflectivity. The thermal infrared channel I has an essentially flat response from 8μ to 13μ. Electronic shaping at the sensor removes the T^4 dependence of the signal, making it a linearly increasing function of scene black body temperature over the range of $210^{\circ}K$ to $310^{\circ}K$.

D. NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) SATELLITE IMAGERY

The photo-quality NOAA satellite imagery was obtained from the Naval Environmental Prediction Research Facility and Naval Postgraduate School archives in Monterey, California. The imagery, forwarded from Fleet Weather Facility, Suitland, Maryland was originally utilized for generating satellite analysis messages for fleet operations.

This study utilized visual imagery derived from the satellite's two-channel scanning radiometer. The imagery is in the form of a hard copy 8 1/2 by 18 inches and covers an area from the near pole latitudes to the equator. The NOAA infrared imagery were not available for the dates analyzed in this study.

The scanning radiometer (SR) is a two-channel scanning instrument sensitive to reflected (visual) energy in the 0.5μ to 0.7μ portion of the spectrum. The visual (VIS) mode of the scanning radiometer has a subsatellite point resolution of 2 nmi. The computer gridded imagery have been corrected to remove apparent compression at the strip edges but there is a loss of resolution along the edges.

E. VERTICAL TIME CROSS SECTIONS

Vertical time cross-sections for McMurdo Station have been constructed for all the case studies presented here. Potential temperature, D-values, mixing ratio and isotherms have been analyzed to obtain detailed information regarding atmospheric thermal and moisture distributions. The synthesis of the vertical time cross-sections, conventional quasi-horizontal analyses, and satellite imagery provides a mode whereby combined horizontal/vertical time continuity of atmospheric variables at one station can be realized.

F. CONSTANT PRESSURE ANALYSES

Southern Hemisphere constant pressure analyses originating from the Australian Weather Bureau in Melbourne and the U. S. Navy Operation DEEP FREEZE weather offices were utilized as first guess fields by the author.

Melbourne surface and 500 mb analyses on microfilm were obtained from the Naval Weather Service Detachment (NWSED), colocated with the National Climatic Center, Asheville, N. C. Surface and various upper-level analyses such as 200 mb, 400 mb and 700 mb originating from the U. S. Navy Christchurch, New Zealand and McMurdo, Antarctica weather offices were obtained from the Meteorological Division, Naval Support Force Antarctica Headquarters, Port Hueneme, California and from NWSED, Asheville, North Carolina, which is the national archive for the Antarctic maps. A complete series of the upper-level analyses are not available, as the level analyzed is somewhat dependent upon the regional aircraft activity; i.e. 400 mb analysis for LC-130 aircraft, 200 mb analysis for C-141 aircraft or 700 mb analysis for Twin Otter aircraft or in the case of aircraft decompression emergencies. In addition, Fleet Weather Facility, Suitland, Maryland; Australian; and Soviet satellite analyses message plots, constructed by Operation DEEP FREEZE personnel, were also available.

The 400 mb level was chosen as a representative upper-tropospheric level because of added data availability from U. S. Navy LC-130 aircraft reports. The 700 mb level was chosen because it presented a representative depiction of the low-level synoptic circulations.

Vortices on satellite imagery and analyses are designated 1) by a letter if they initially appear at approximately the same position at 700 and 400 mb, 2) by a letter preceded by number indicating the singular

constant-pressure level at which analyzed, and 3) by an "L" or "H" when not an integral part of the analysis discussion. Contours at both levels are labeled in decameters. Plotted temperature data are in deg C, while contour heights at 400 mb are plotted in decameters and the heights at 700 mb are plotted in whole meters with the thousandths figure omitted. 700 mb contour values enclosed in parentheses indicate extrapolated data (as at South Pole Station or corrected data).

VI. ANALYSIS PROCEDURE

With a maximum of four Antarctic observation stations with rawinsonde capability in the area of analysis, it is necessary to supplement this sparse concentration of conventional data with satellite imagery and available aircraft data.

IR and VIS satellite imagery are used extensively in regions where conventional data are lacking. Comparison of IR and VIS imagery frequently allows the discrimination of two or more cloud layers when the height and nature of the underlying earth's surface are known. In this study the IR and 400 mb analyses are viewed as a pair with respect to the upper-tropospheric circulations (500 mb and above) and similarly, the VIS and 700 mb analyses are viewed as a pair with respect to the lower-level tropospheric circulations (below 500 mb).

The above procedure is used in the December and January case studies that follow; thus, analyses at two rather than at all mandatory levels in the troposphere are generated.

VII. CASE STUDY OF THE ATMOSPHERIC EVENTS ASSOCIATED WITH THE 11 JANUARY 1976 SIGNIFICANT WEATHER DAY AT McMURDO STATION, ANTARCTICA (Figs.5-36)

A. INTRODUCTION

The atmospheric events leading up to the 11 January 1976 significant weather day at McMurdo, Antarctica were of considerable importance to the Antarctic scientific community and the Naval Support Force. It was the threat of major cyclogenesis in the Ross Sea which initiated the evacuation of scientific personnel and equipment from the northern Ross Ice Shelf on or about 9 January 1976.

The period of study began with unsettled weather on 5 January, continuing through 11 January, with a light snow falling on five of the seven days (Figs. 34 and 35). The significant weather at McMurdo occurred between 0000 GMT and 0700 GMT on 11 January 1976 when visibility dropped to 5/8 mile in light snow and blowing snow with maximum winds from 170 deg at 20 kt gusting to 40 kt. Although this significant weather period was brief in duration, there existed the potential of cyclogenesis in the Ross Sea area with a more extended period of inclement weather at McMurdo and over the surrounding area.

The synoptic weather pattern leading to the significant weather day at McMurdo involved a deepening, eastward moving long-wave trough approaching the longitude of the western Ross Sea on 9 January. Satellite imagery indicated the meridional transport of moisture from the vicinity of New Zealand to the Ross Sea between 9 and 11 January.

The 400 mb level was chosen as a representative upper-tropospheric level because of added data availability from U. S. Navy LC-130 aircraft reports. The 700 mb level was chosen because it presented a representative depiction of the low-level synoptic circulations.

Climatological circulation and thermal patterns for the month of January appear in Fig. 5 (Taljaard et al, 1969). Climatology was unavailable for the 400 mb level, therefore 500 mb was chosen as the closest mandatory level. The circulation implied by the 700 mb contours (Fig. 5-C) indicates light southerly winds at McMurdo associated with an area of relatively low pressure on the Ross Ice Shelf. Zonal westerly flow extends northward from the coastline near 170E through New Zealand at 700 mb. Coldest air (Fig. 5-D) is centered over eastern Antarctica where surface elevations actually exceed 700 mb over a considerable area. At the 500 mb level (Fig. 5-A), light westerly winds are the norm for McMurdo. The major synoptic feature is a polar vortex centered between South Pole and the Ross Ice Shelf. Coldest air (Fig. 5-B) is somewhat closer to the Pole at 500 mb compared to 700 mb. A discussion of the 700 and 400 mb circulations for the period of study, 8-11 January 1976, follows.

B. CASE STUDY ANALYSIS (00 GMT 08 January - 12 GMT 11 January 1976)

1. <u>0000 GMT, 08 January 1976 Analyses (Figs. 6-9)</u>

a. Upper Troposphere (400 mb: Fig. 6)

Aircraft reports show westerly winds from New Zealand to 73S along the 170E meridian and a cyclonic vortex center (4-A) northwest of McMurdo. Considerable noise was present in the DMSP IR satellite imagery (Fig. 8) for this time, but upper-level ridging over the continent in the vicinity of 130W was indicated by the anticyclonically curved returns from

[illegible]

[illegible]

[illegible]

[illegible]

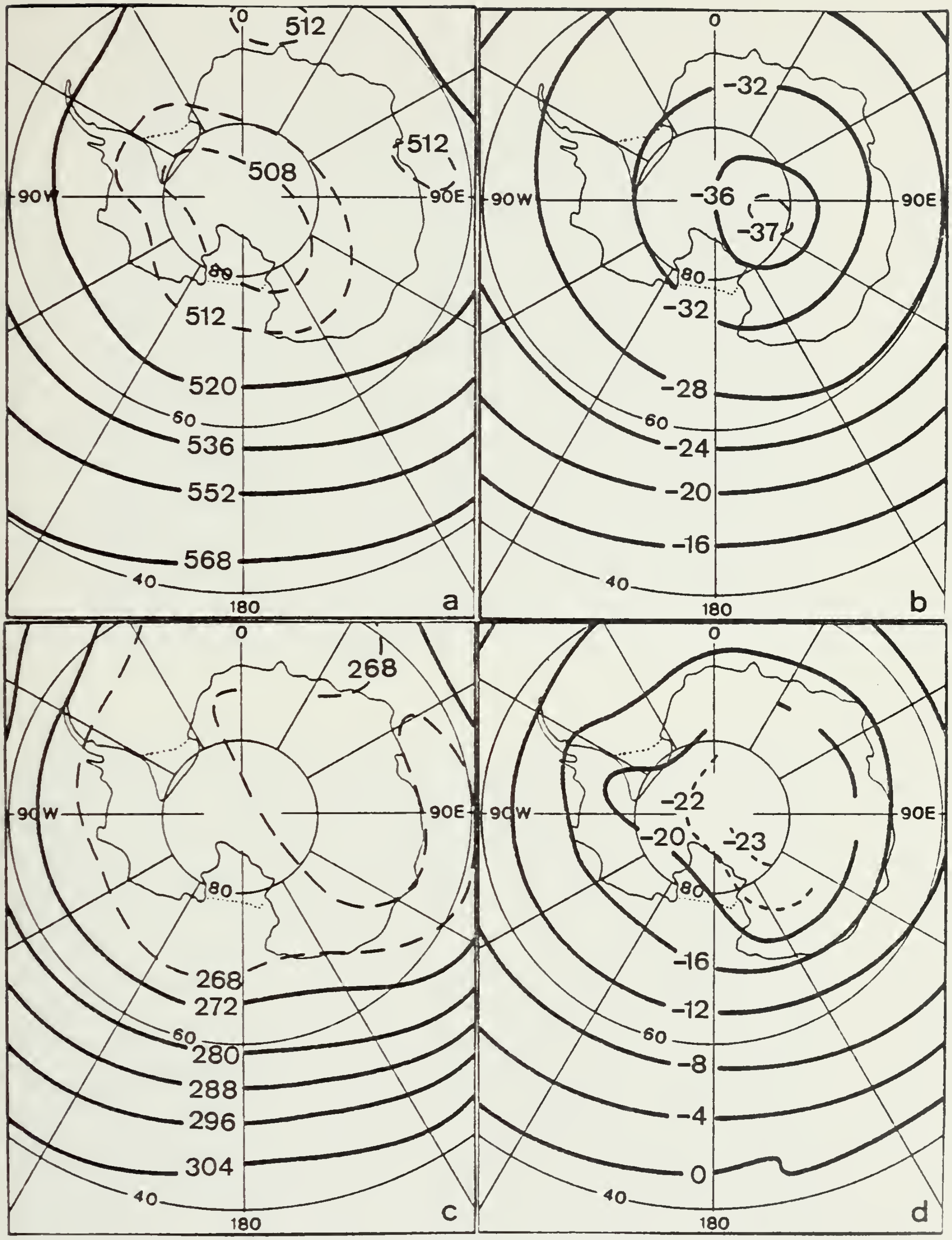


Figure 5. Mean Antarctic circulation and thermal patterns for January -
a. 500 mb contours
b. 500 mb isotherms
c. 700 mb contours
d. 700 mb isotherms

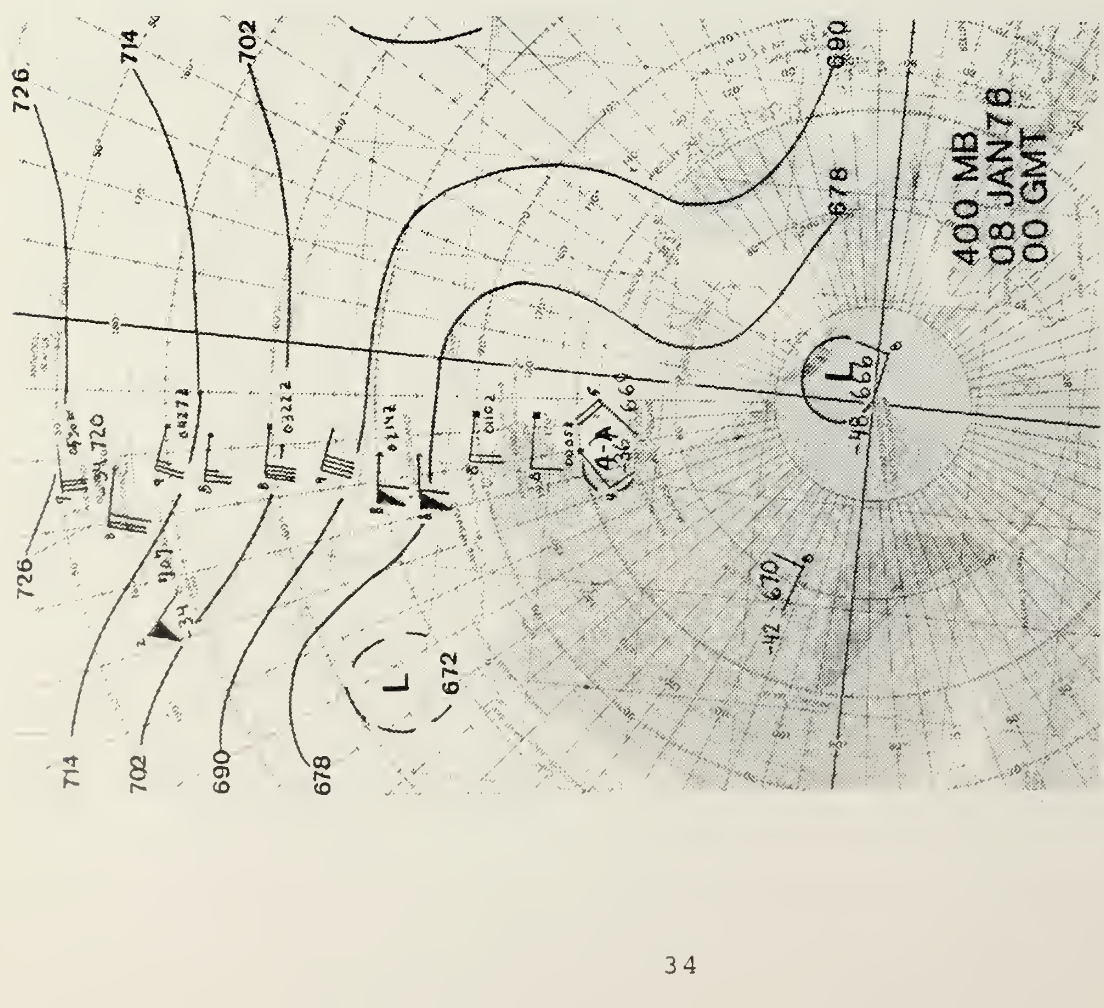


Figure 6

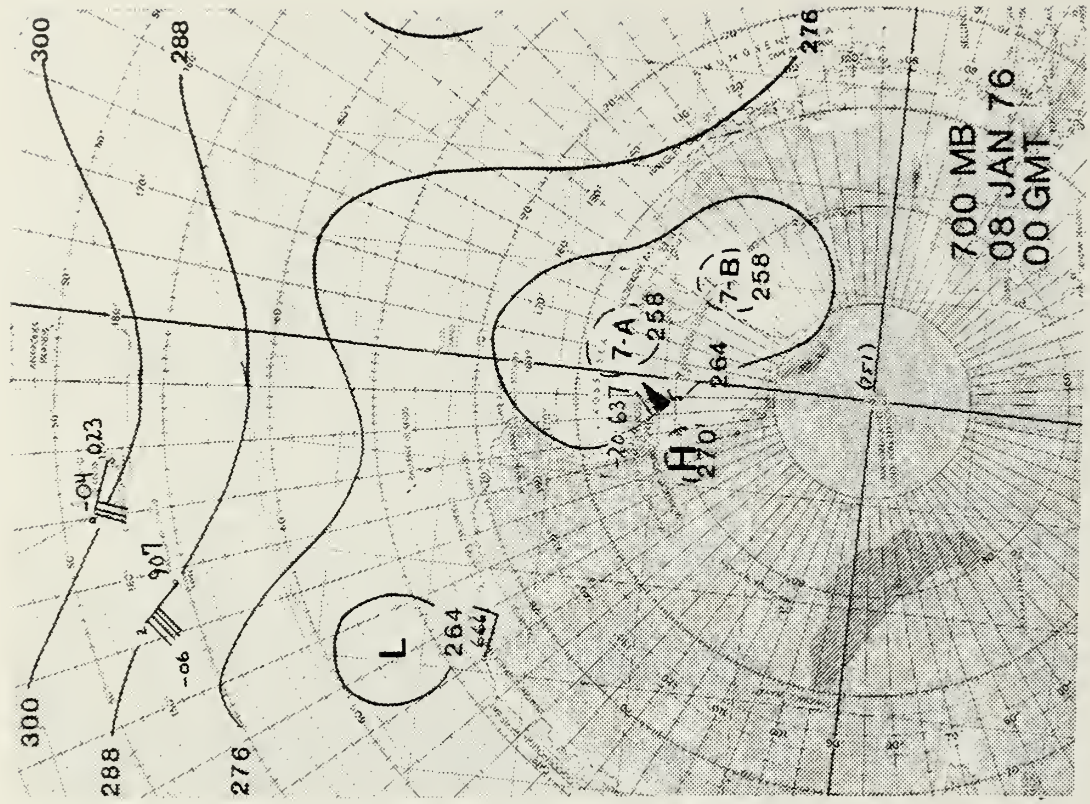


Figure 7

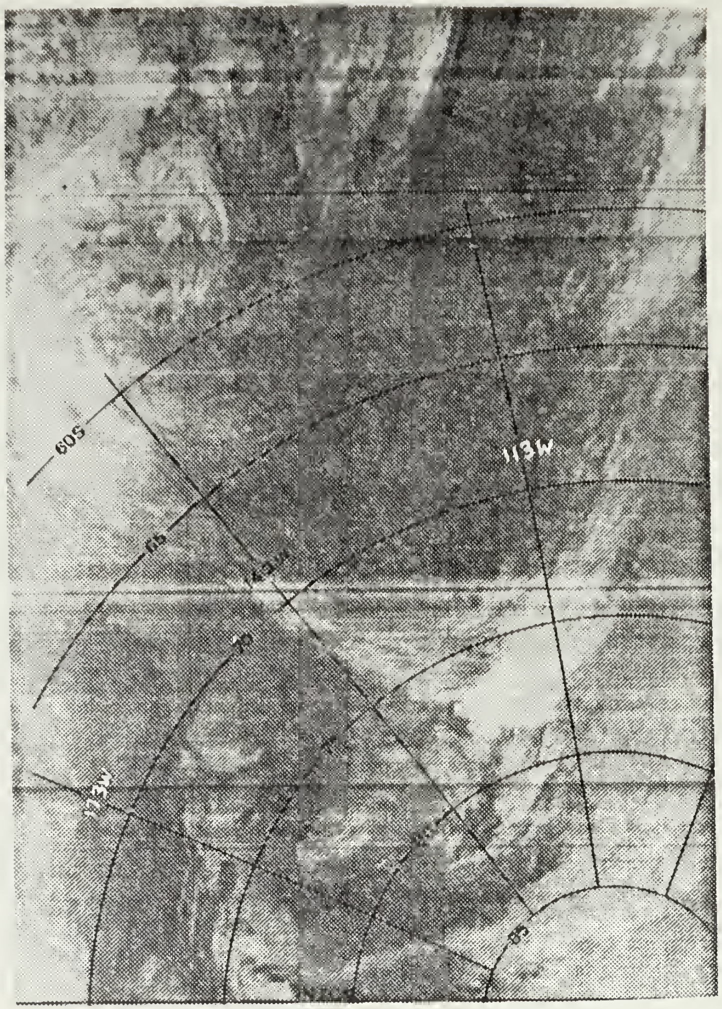


Figure 8. DMSP IR satellite observation, about 0200 GMT 08 January 1976.

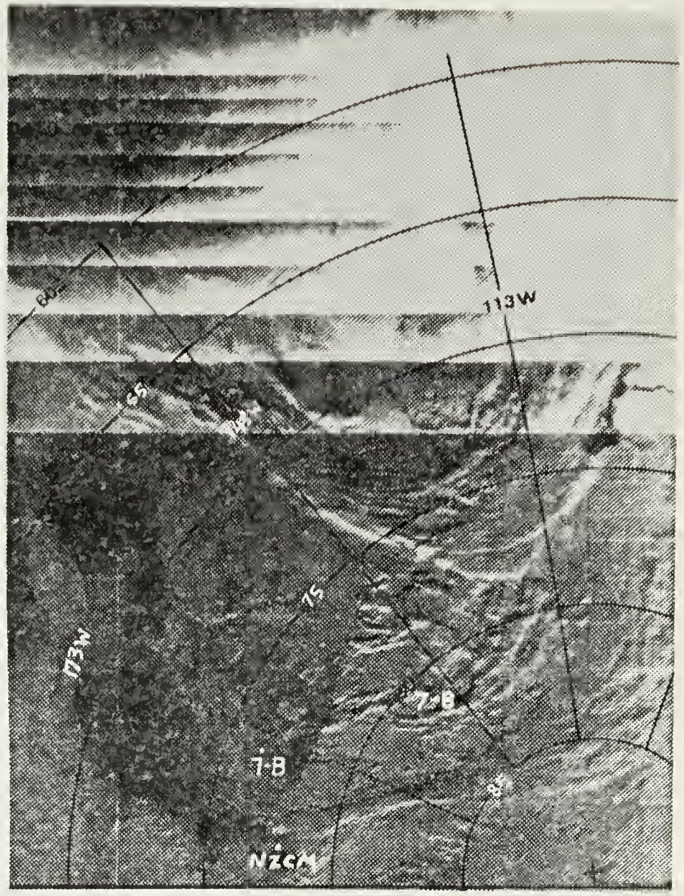


Figure 9. DMSP VIS satellite observation, about 0200 GMT 08 January 1976.

high tropospheric clouds. It is noted that the clouds do not terminate in the vicinity of the ridge line as is generally the case in mid-latitude nephanalyses.

b. Lower Troposphere (700 mb: Fig. 7)

DMSP visual satellite imagery (Fig. 9) suggests two cyclonic vortices in the vicinity of the Ross Ice Shelf. Vortex (7-A) can be seen just north of the Ross Ice Shelf and vortex (7-B) over the extreme eastern Ross Ice Shelf. Cyclonic cloud curvature, which is detectable only on the visual satellite imagery, indicates that these vortices are likely to be low-level circulation features.

2. 1200 GMT, 08 January 1976 Analyses (Figs. 10-12)

a. Upper Troposphere (400 mb: Fig. 10)

As inferred by the east-southeasterly wind at McMurdo, vortex 4-A has drifted eastward about two deg lat. Ridging is analyzed south of McMurdo. NOAA-4 visual satellite imagery (Fig. 12) shows a major cold low in the vicinity of 60S 140W.

b. Lower Troposphere (700 mb: Fig. 11)

Transposing the 25 kt southeasterly wind at McMurdo onto the satellite imagery and tracing the path of a hypothetical parcel of air along the cloud striations indicates an anticyclonic vortex (7-Z) centered about 120 nmi south-southwest of McMurdo. The effect of topography on the clouds is clearly evident in this feature. North of the anticyclonic center, orographic lifting occurs as moisture and clouds from the Ross Ice Shelf are lifted from 100 ft msl to the 7000 ft msl polar plateau. South of the vortex center, a downslope trajectory is present and the air parcels are adiabatically heated and evaported in returning to the ice shelf. The result is a tongue of clear air extending onto the ice shelf

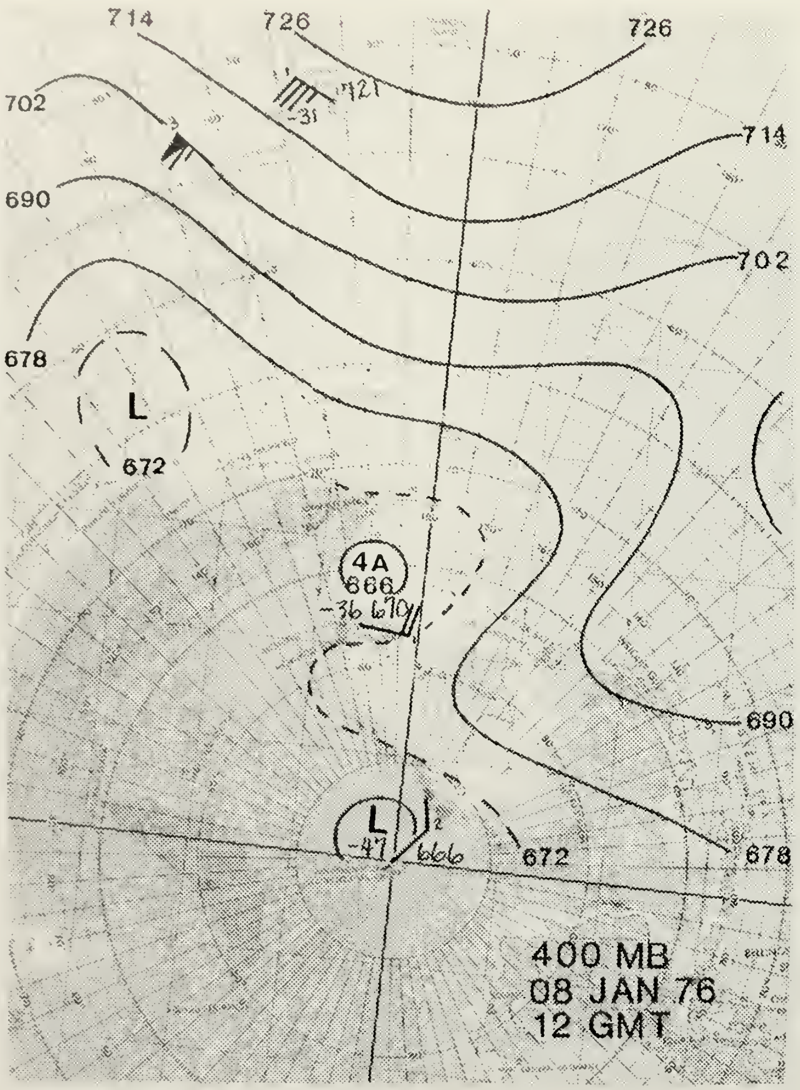


Figure 10

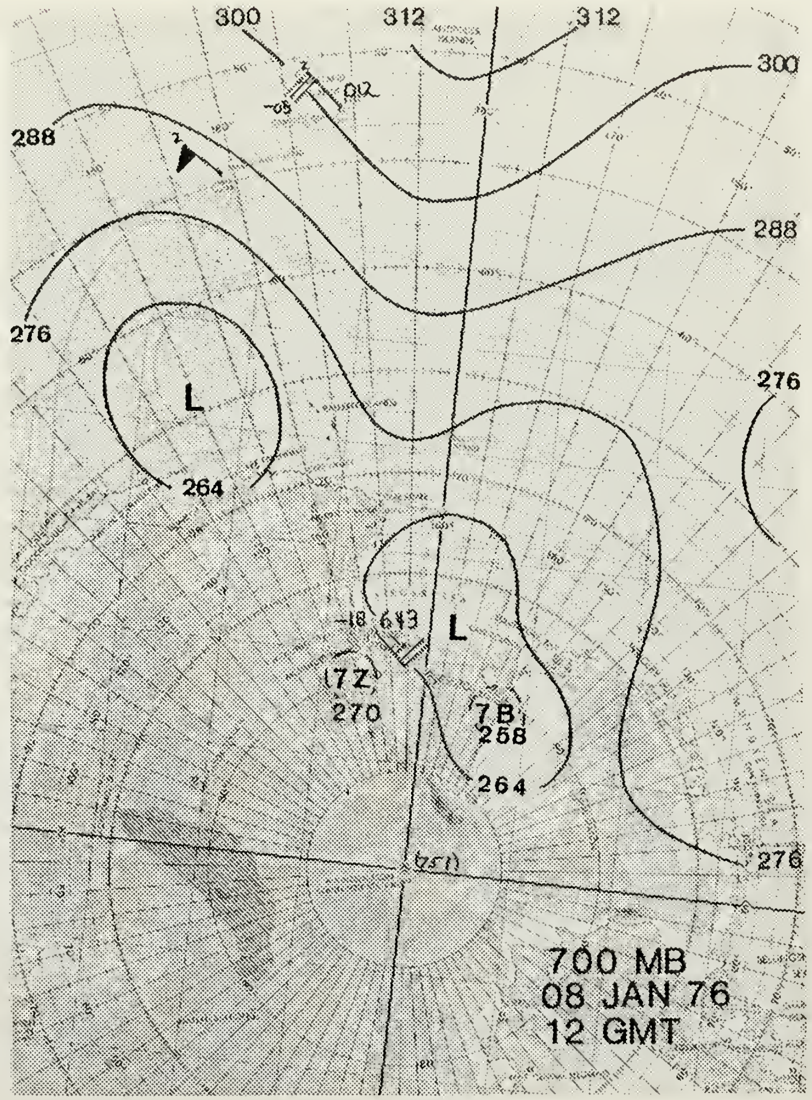


Figure 11

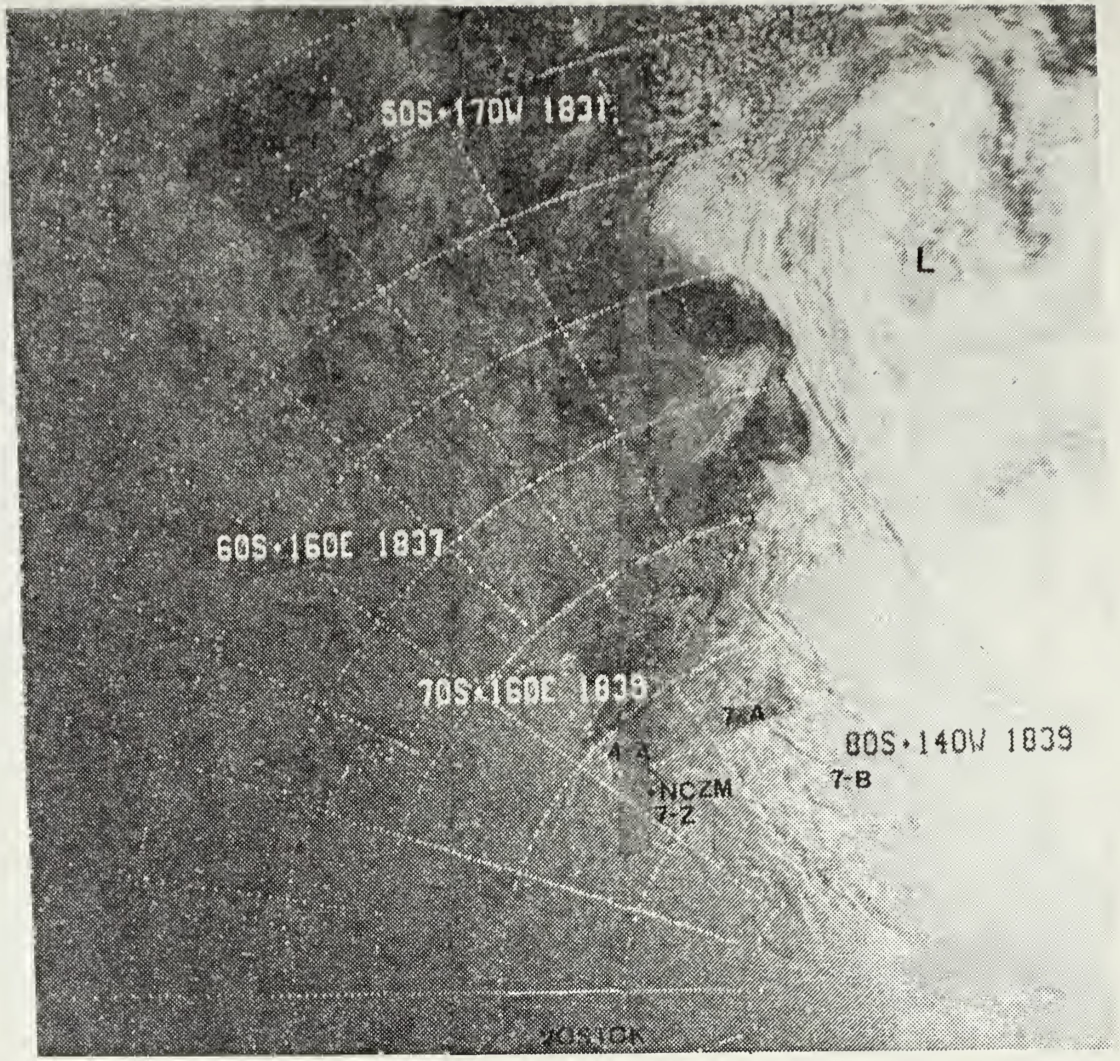


Figure 12. NOAA-4 PASS-5247 T-11 SEN-1 VIS 1/8/76 1845.

and curving toward McMurdo. It is noted that the simplicity of the circulation is complicated by clouds derived from the synoptic-scale moisture intrusion from mid-latitudes to the east of McMurdo. McMurdo surface observations for this day indicate that maximum wind gusts of 70 kt from the south were observed 4 1/2 hours prior to the time of the NOAA-4 satellite observation. The vertical sounding (Fig. 34) for this time period shows no support for a surface wind of this magnitude. This is an example of short period locally induced katabatic winds.

Although considerable cloudiness exists on the Ross Ice Shelf, the positions of vortices 7-A and 7-B are difficult to locate with the NOAA imagery.

3. <u>0000 GMT, 09 January 1976 Analyses (Figs. 13-16)</u>

a. Upper Troposphere (400 mb: Fig. 13)

Aircraft reports assist in positioning cyclonic vortex 4-A approximately two deg lat due north of McMurdo. DMSP IR satellite imagery (Fig. 15) outlines the anticyclonic flow about an upper-level ridge near 180 deg, as depicted by bright return and anticyclonic curvature in the cloud system, extending poleward to 72S. At this time McMurdo, at upper levels, is under the influence of air which is being recirculated from the continent through the western Ross Sea. To the east, middle/high clouds associated with ridging near the 125W meridian has extended to 80S.

b. Lower Troposphere (700 mb: Fig. 14)

The DMSP visual satellite imagery (Fig. 16) shows vortex 7-B on the Ross Ice Shelf. A height increase of 28 gpm and a 10 kt decrease in wind speed at McMurdo in the past 12 hours, coupled with increased ridging in the northern Ross Sea and eastern Ross Ice Shelf, appears to be associated with the filling of cyclonic vortex 7-A. Clouds are being

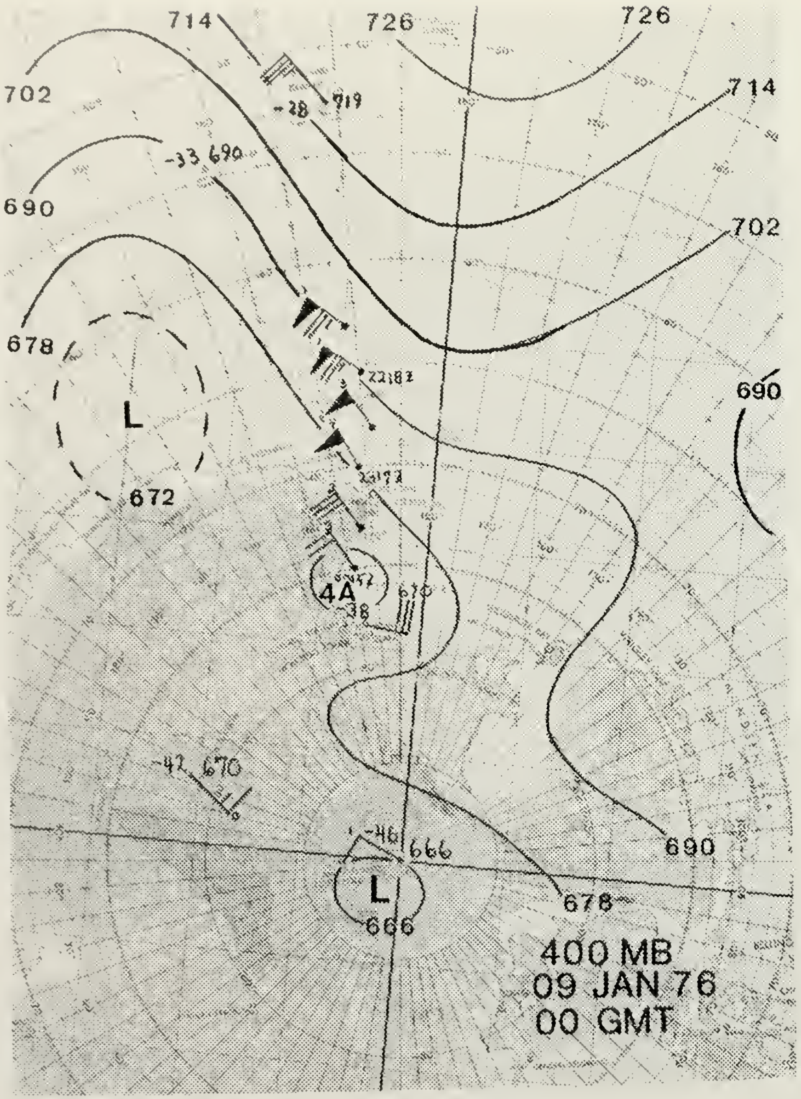


Figure 13

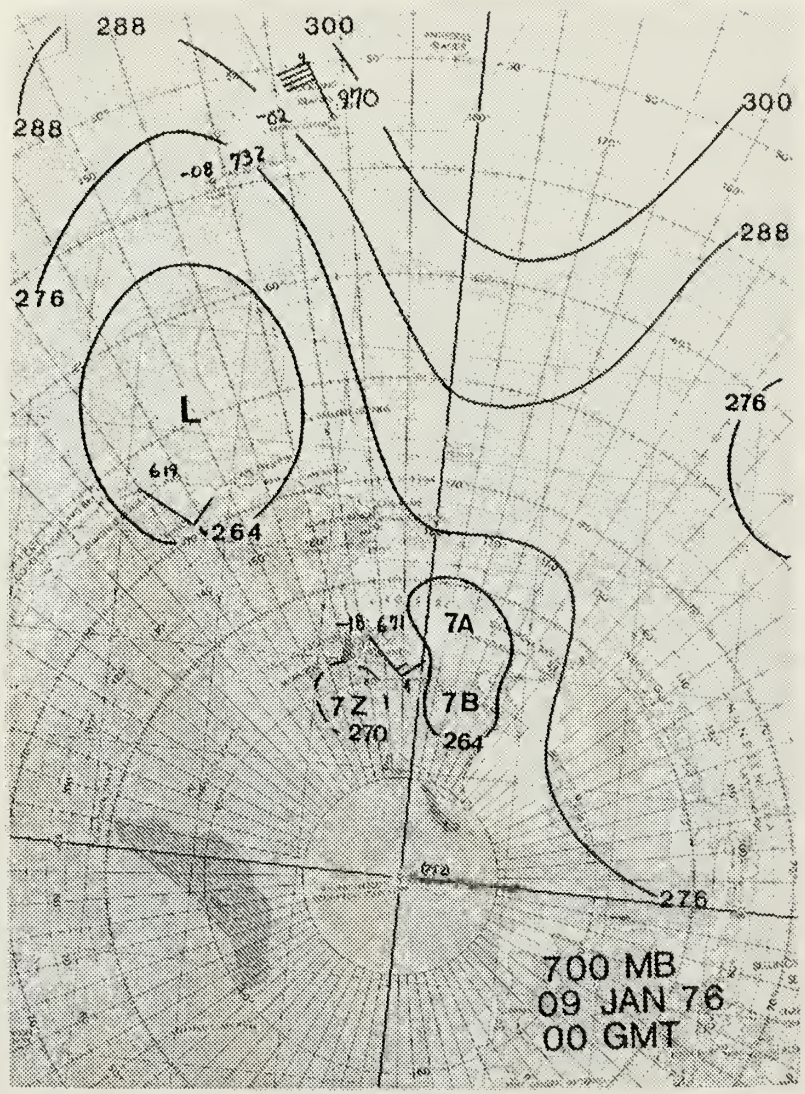


Figure 14

Figure 15. DMSP IR satellite observation, about 0200 GMT 09 January 1976.

Figure 16. DMSP VIS satellite observation, about 0200 GMT 09 January 1976.

advected onto the Ross Ice Shelf by way of the southern extent of the ridge in West Antarctica. Anticyclonic curvature associated with anticyclone 7-Z is still visible but not as well organized as in the previous satellite observation.

4. 1200 GMT, 09 January 1976 Analyses (Figs. 17-19)

a. Upper Troposphere (400 mb: Fig. 17)

Aircraft reports show a region of sharp horizontal wind shear from 67S to 70S where west-northwesterly winds at 120 kt shift to north-northwesterly at 25 kt. NOAA satellite imagery (Fig. 19) shows a vast cloud shield extending meridionally from New Zealand southward to approximately the same position as the area of maximum wind. In that region the flow turns toward the southeast and enters the eastern Ross Sea. Aircraft reports and the McMurdo observation indicate vortex 4-A has moved westward once again. The brunt of the associated synoptic-scale cloud shield has not yet affected McMurdo.

b. Lower troposphere (700 mb: Fig. 18)

The NOAA visual satellite imagery (Fig. 19) indicates anticyclone 7-Z remains south of McMurdo as evidenced by a tongue of clear air on the Ross Ice Shelf approximately 6 deg lat south-southeast of McMurdo. Vortex 7-B is not clearly defined in the satellite imagery but is carried on the analysis for reason of continuity until a more definitive observation is available.

5. 0000 GMT, 10 January 1976 Analyses (Figs. 20-23)

a. Upper Troposphere (400 mb: Fig. 20)

DMSP IR satellite imagery (Fig. 22) depicts bright returns on cloud bands extending along the 180 meridian to 74S and then eastward to the eastern Ross Sea where the cloud bands diverge. Some of the cloud

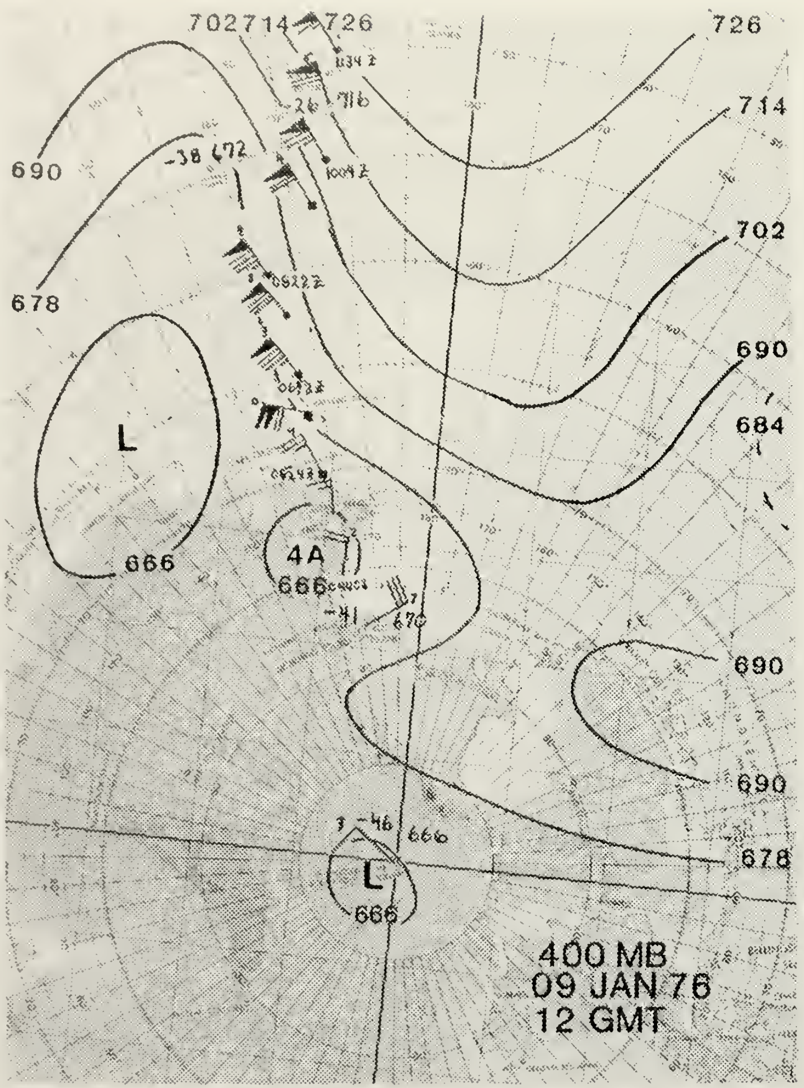


Figure 17

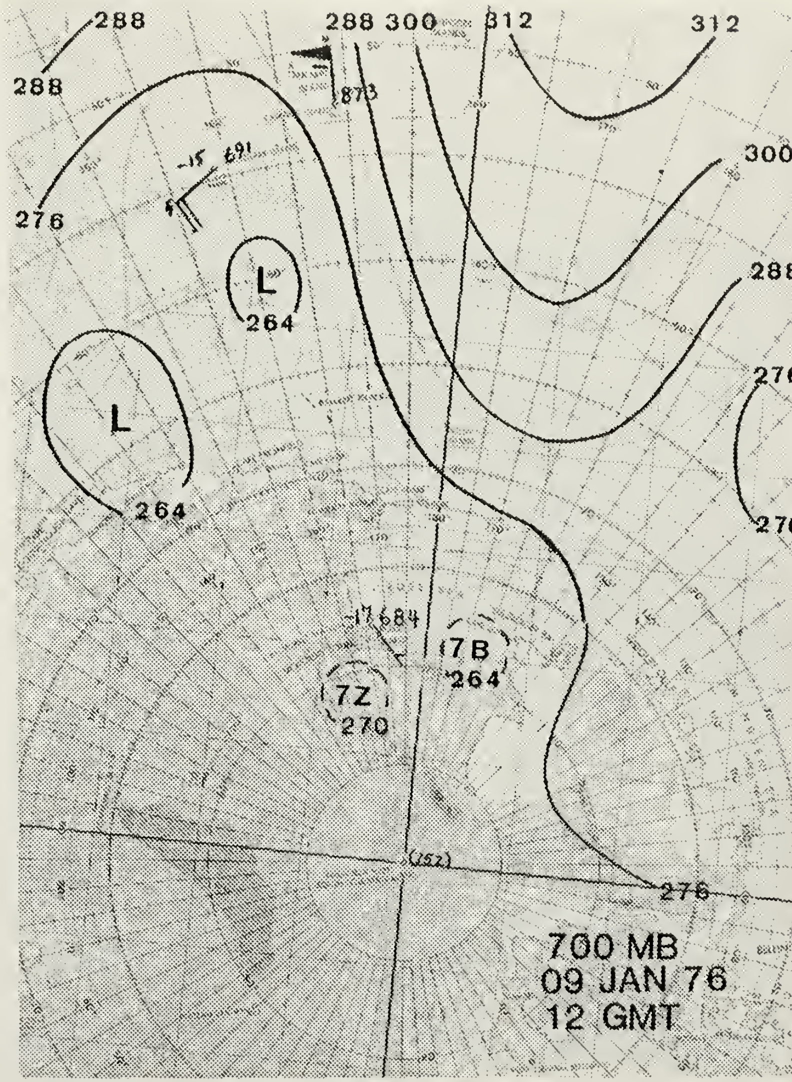


Figure 18

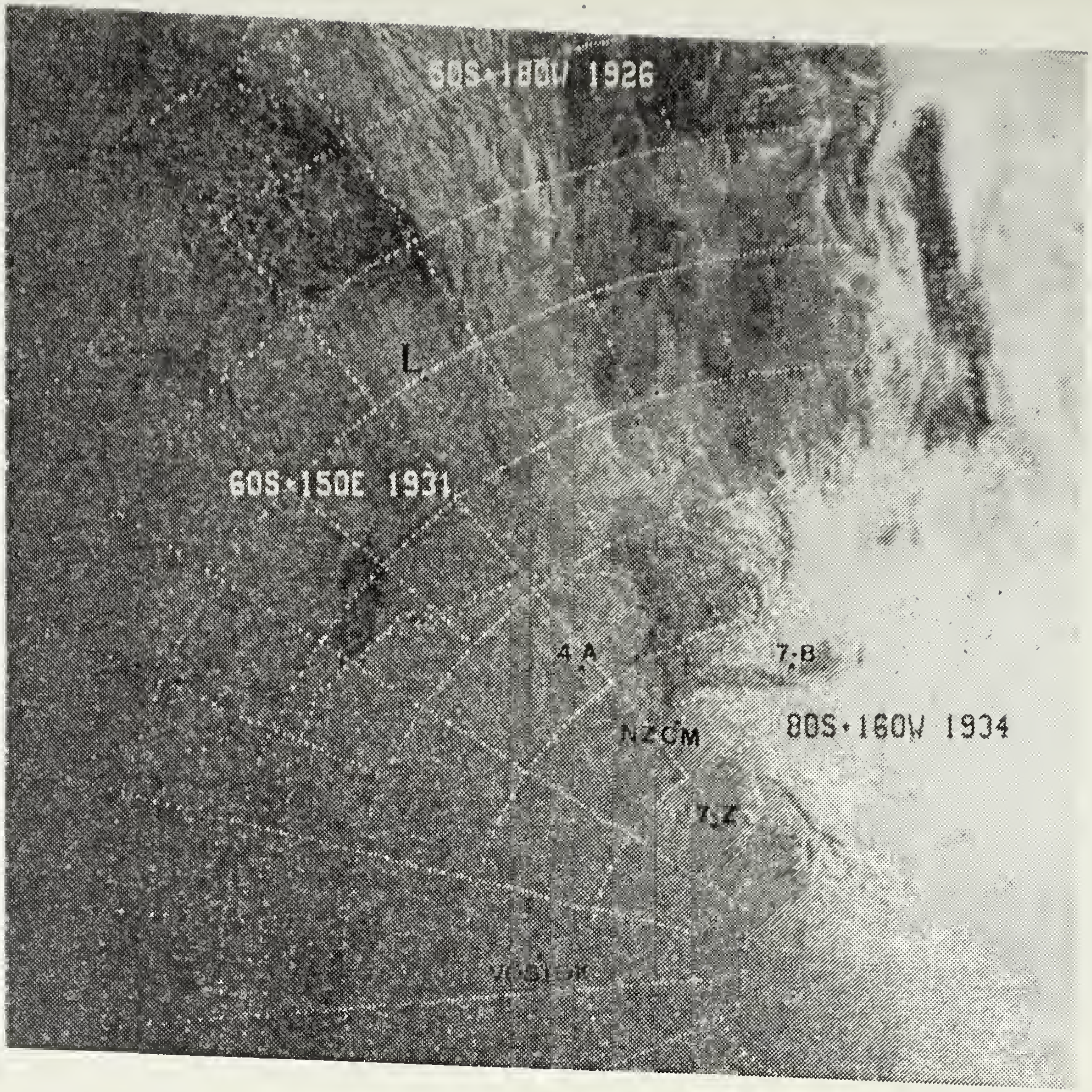


Figure 19. NOAA-4 PASS-5260 T-12 SEN-1 VIS 1/9/76 1940.

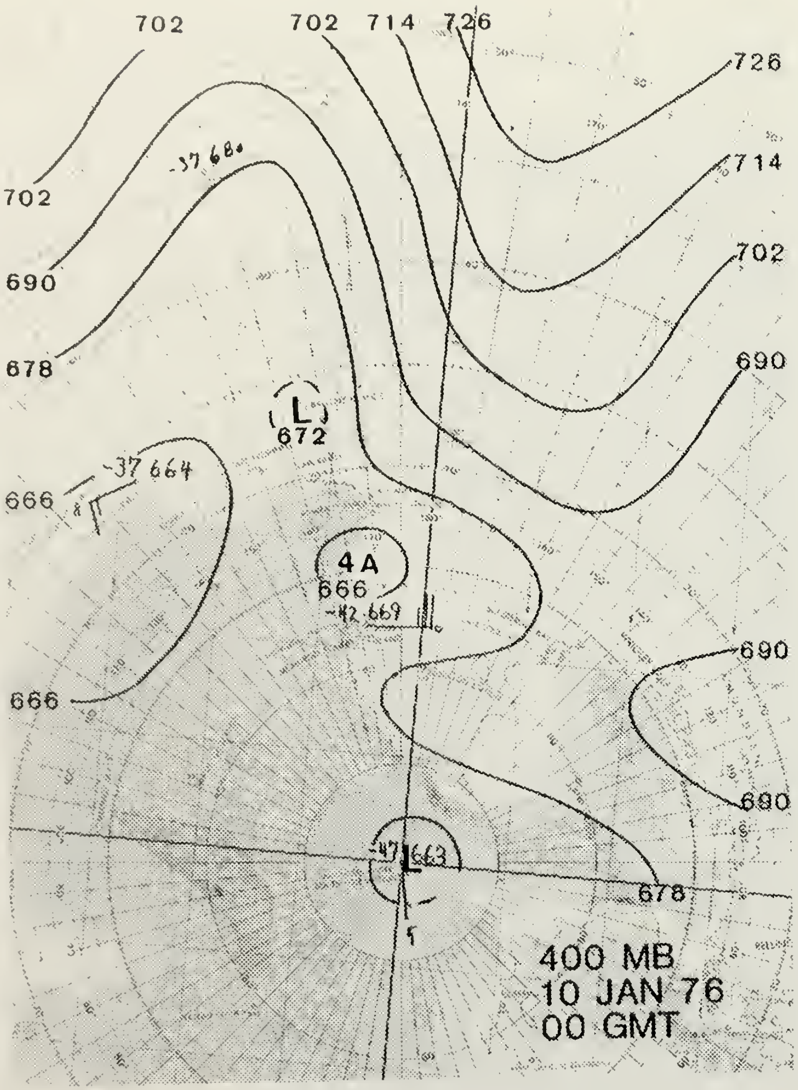


Figure 20

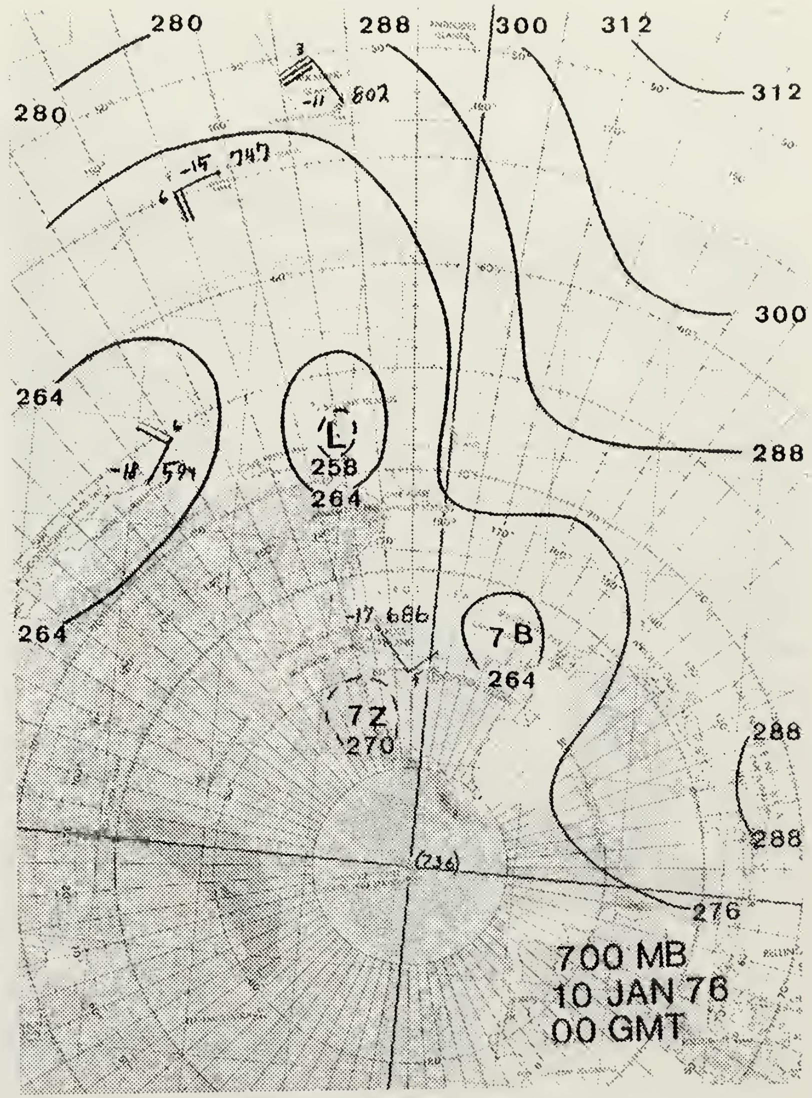


Figure 21

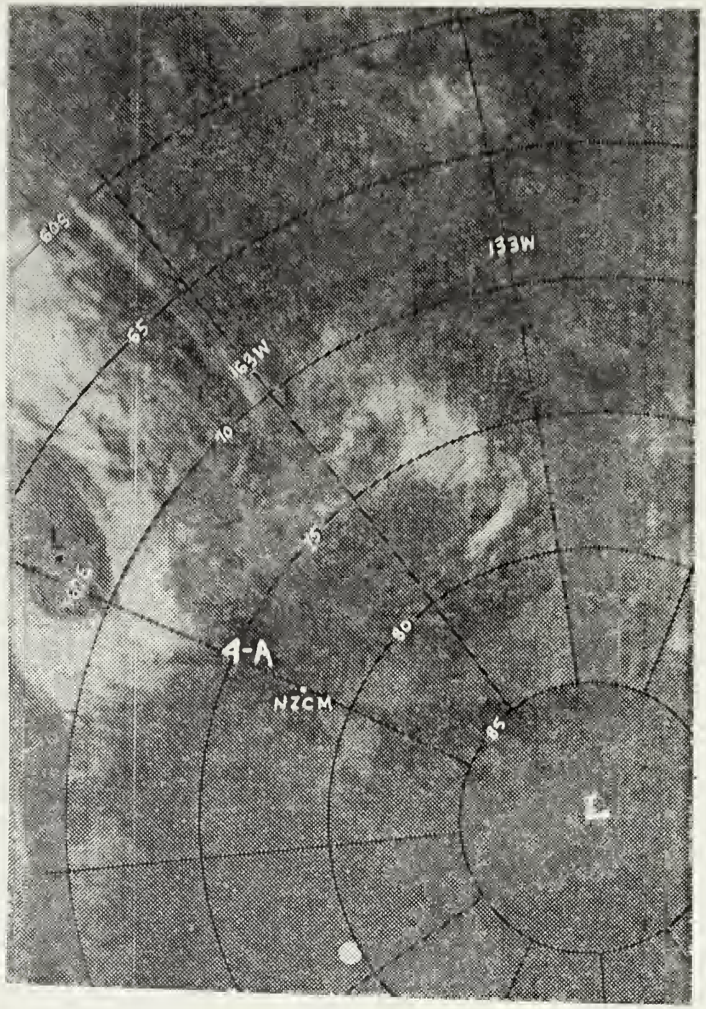


Figure 22. DMSP IR satellite observation, about 0300 GMT 10 January 1976.

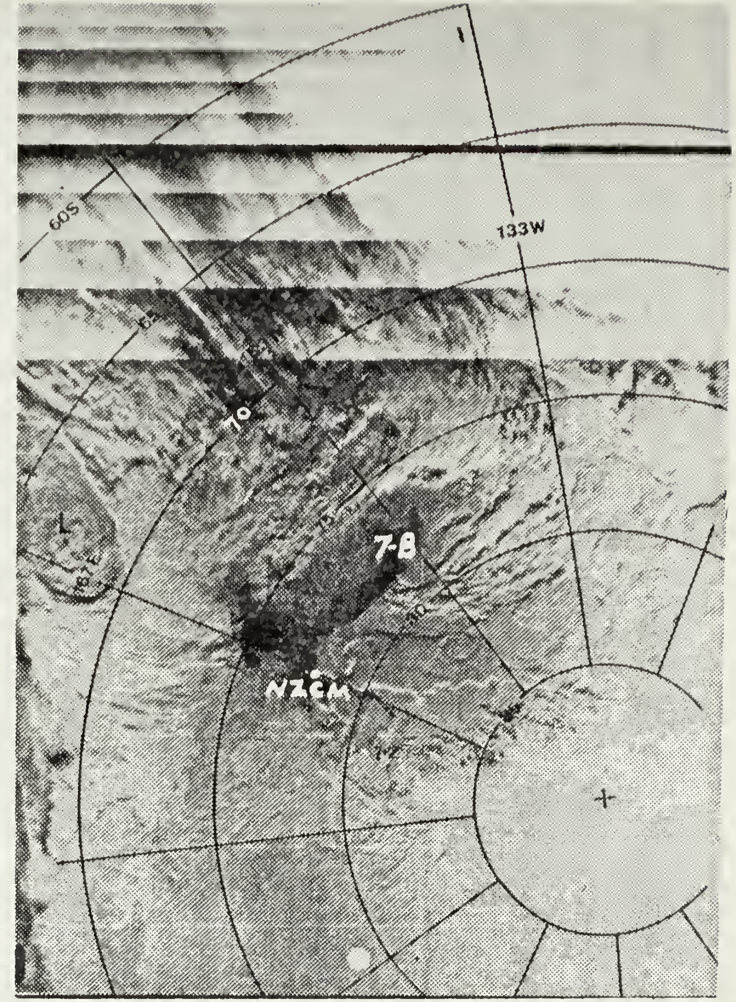


Figure 23. DMSP VIS satellite observation, about 0300 GMT 10 January 1976.

striations turn northward around the ridge and others curve cyclonically onto the eastern Ross Ice Shelf. The meridional flow which had been approaching McMurdo no longer approaches directly but must first flow around the eastern Ross Sea. As indicated by an easterly wind at McMurdo, vortex 4-A has moved eastward again. A sharp trough also is depicted from vortex 4-A eastward, thus keeping McMurdo under the circulation of drier recirculated air.

b. Lower Troposphere (700 mb: Fig. 21)

DMSP visual satellite imagery (Fig. 23) shows anticyclone 7-Z has remained essentially stationary. It is noted that much of the cloudiness which had been wedged against the Trans-Antarctic Mountain Range has moved northward. The observation of this type of movement appears to be a means by which one can deduce existing wind directions. Vortex 7-B, which was not visible on the previous NOAA satellite observation, has been clearly located just north of the Ross Ice Shelf beneath the trough analyzed on the 400 mb analysis.

6. <u>1200 GMT, 10 January Analyses (Figs. 24-26)</u>

a. Upper Troposphere (400 mb: Fig. 24)

McMurdo winds have shifted from east-southeast at 25 kt to north-northwest at 25 kt with a 10 gpm drop in height. This indicates that vortex 4-A has moved southwestward. The NOAA satellite imagery (Fig. 26) for this time period continues to show the eastward progression of the meridional transport of moisture. The major cloud band axis at 1800 GMT is centered near the 170W meridian, advecting moisture onto the Ross Ice Shelf by way of the eastern Ross Sea. Troughing present in the Ross Sea on previous days is being replaced by a building ridge. The satellite imagery indicates a large area of cyclonic curvature in the cloud bands

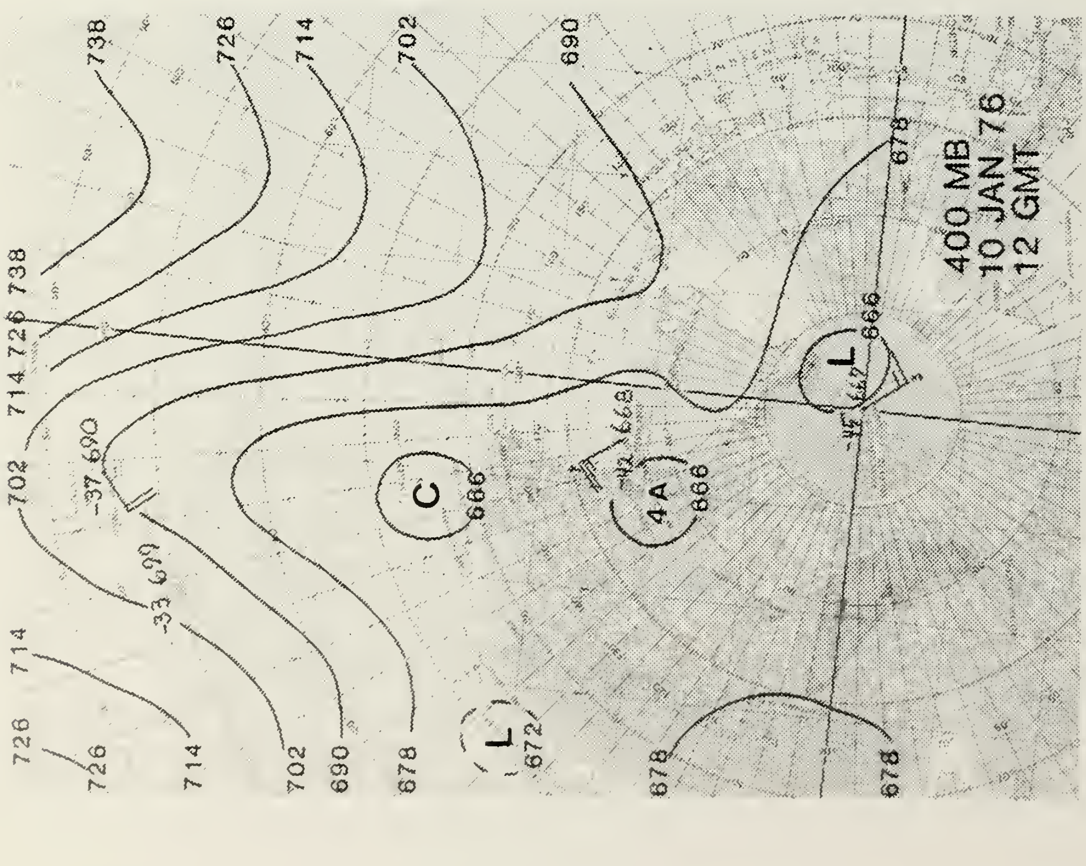


Figure 24

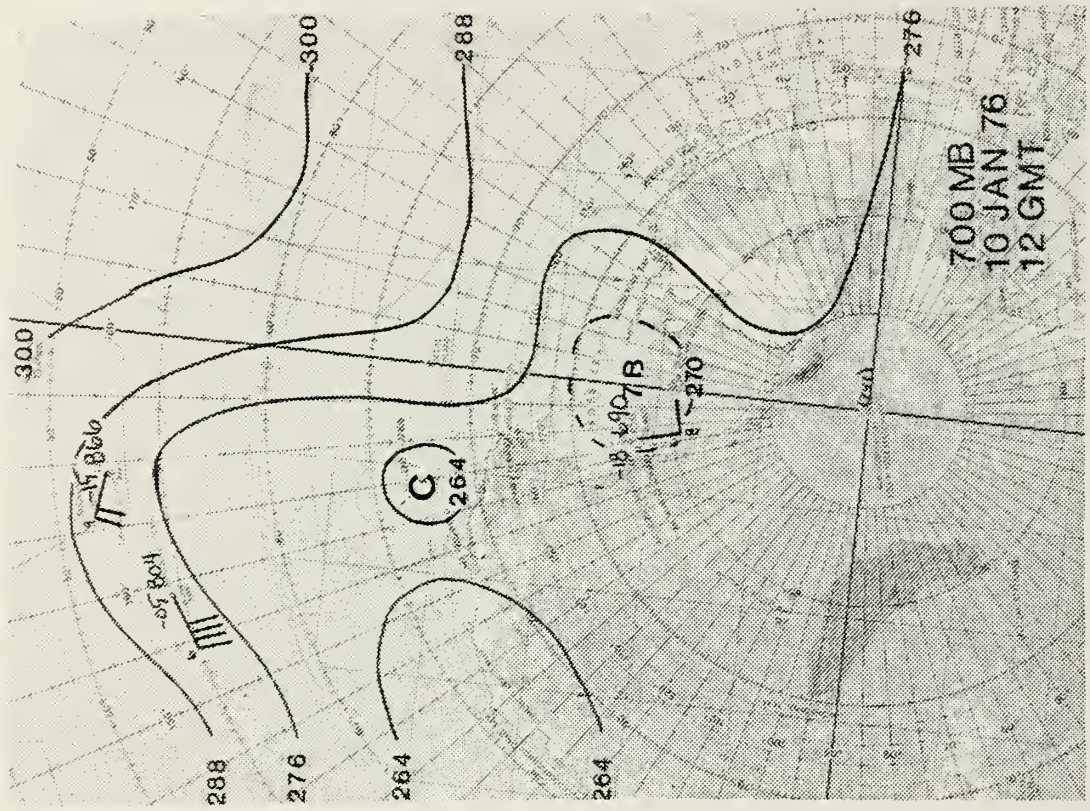


Figure 25

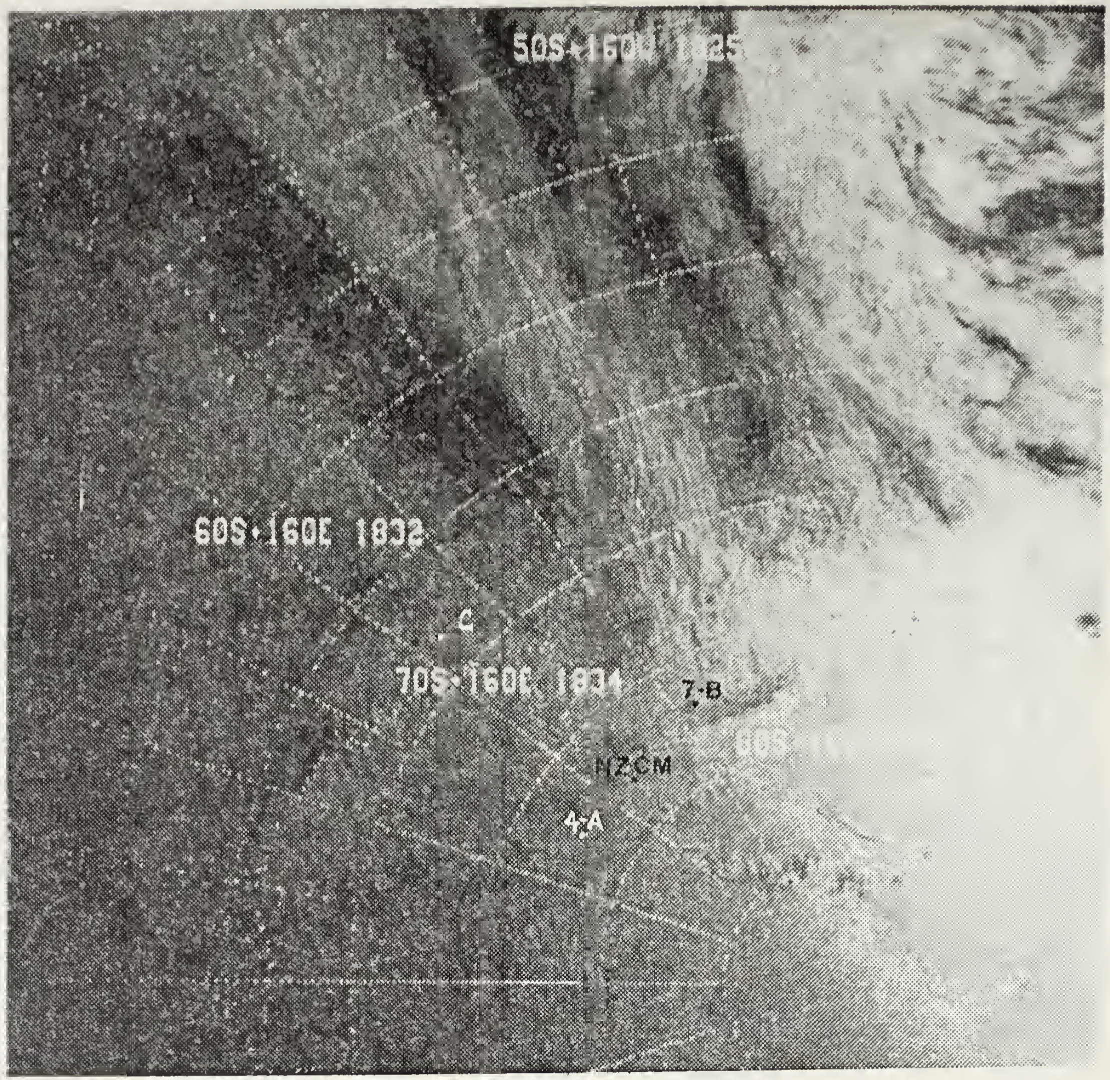


Figure 26. NOAA-4 PASS-5272 T-11 SEN-1 VIS 1/10/76 1840.

about 10 deg lat north of McMurdo, indicative of a closed vortex C, as analyzed.

b. Lower Troposphere (700 mb: Fig. 25)

With the strong advection of upper-level cloudiness into the Ross Sea, the location of vortex 7-B is not observed in the NOAA satellite imagery (Fig. 26). The 700 mb southerly wind at McMurdo indicates a circulation still exists but as indicated by the 400 mb analysis, upper-level ridging aloft weakens the low-troposphere cyclonic circulation.

7. <u>0000 GMT, 11 January 1976 Analyses (Figs. 27-30)</u>

a. Upper Troposphere (400 mb: Fig. 27)

Cyclonic circulation 4-A no longer appears as a separate entity but is now part of vortex 4-C, centered north-northwest of McMurdo. The DMSP IR satellite imagery (Fig. 29) does not reflect the 400 mb northeast wind observed at McMurdo. The cloud curvature observed reflects southeasterly winds which are found beneath the 400 mb level. (See cross-section, Fig. 34.) Over the previous 12-hour period there has been considerable building of the ridge on the Ross Ice Shelf. The McMurdo 400 mb observation shows a 90 gpm height rise. The vertical time cross section shows a mixing ratio maximum of 1.4 gm/kg at the 550 mb level thus indicating this as the major level of mid-tropospheric moisture advection. Warm air advection at the 400 mb level was noted as temperatures rose $10^{\circ}C$ in 12 hours.

b. Lower Troposphere (700 mb: Fig. 28)

The McMurdo 700 mb observation shows a height fall of 14 gpm with a southeasterly wind. DMSP visual satellite imagery (Fig. 30) shows vortex 7-B about three deg lat northeast of McMurdo. Moisture which had been advected onto the Ross Ice Shelf now has a steering mechanism for advection over McMurdo. During the next seven hours McMurdo surface

[illegible]

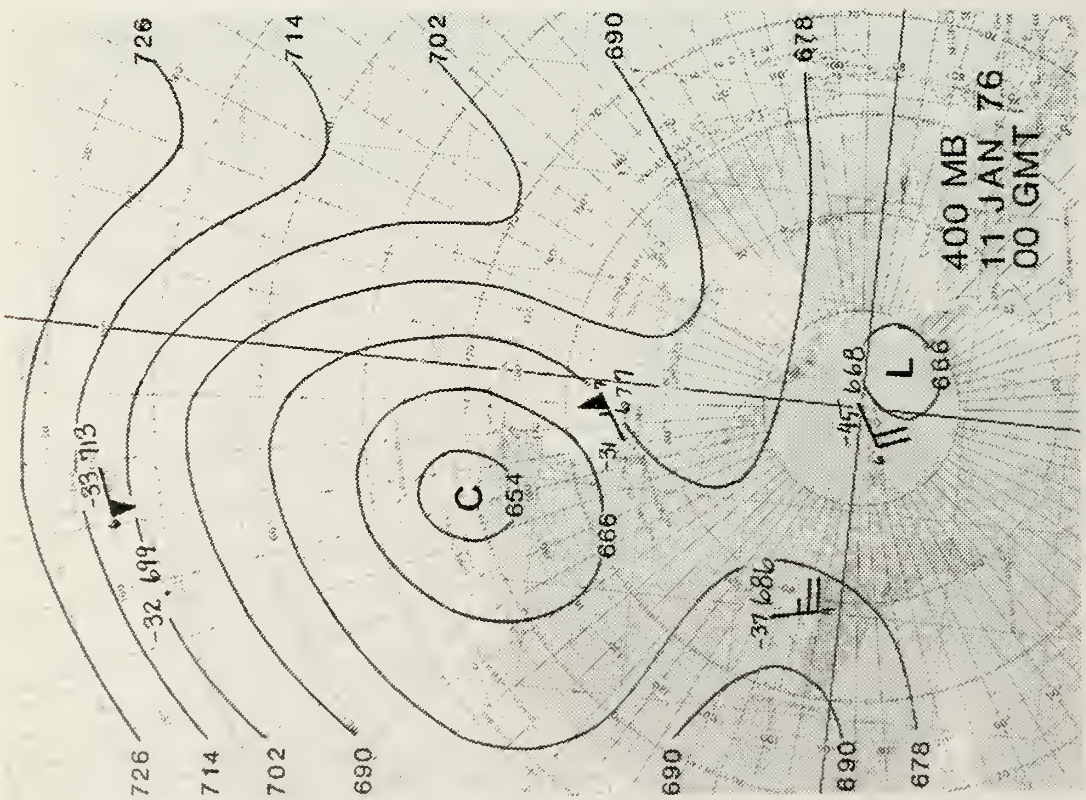


Figure 27

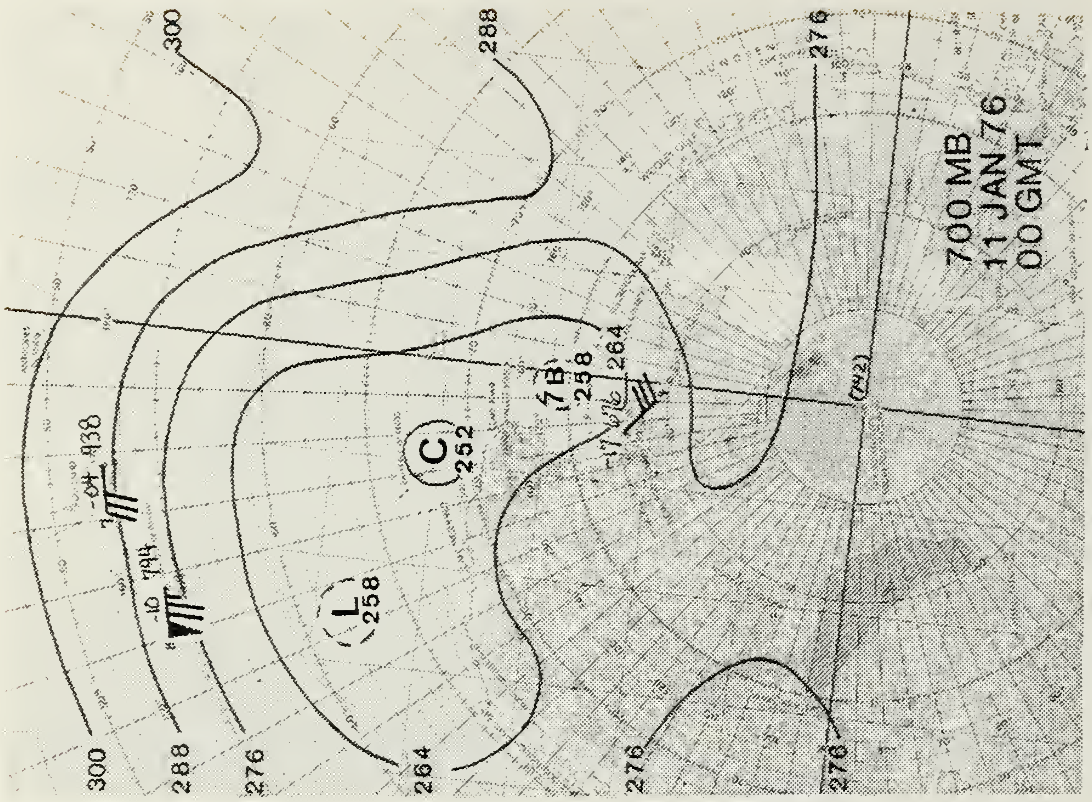


Figure 28

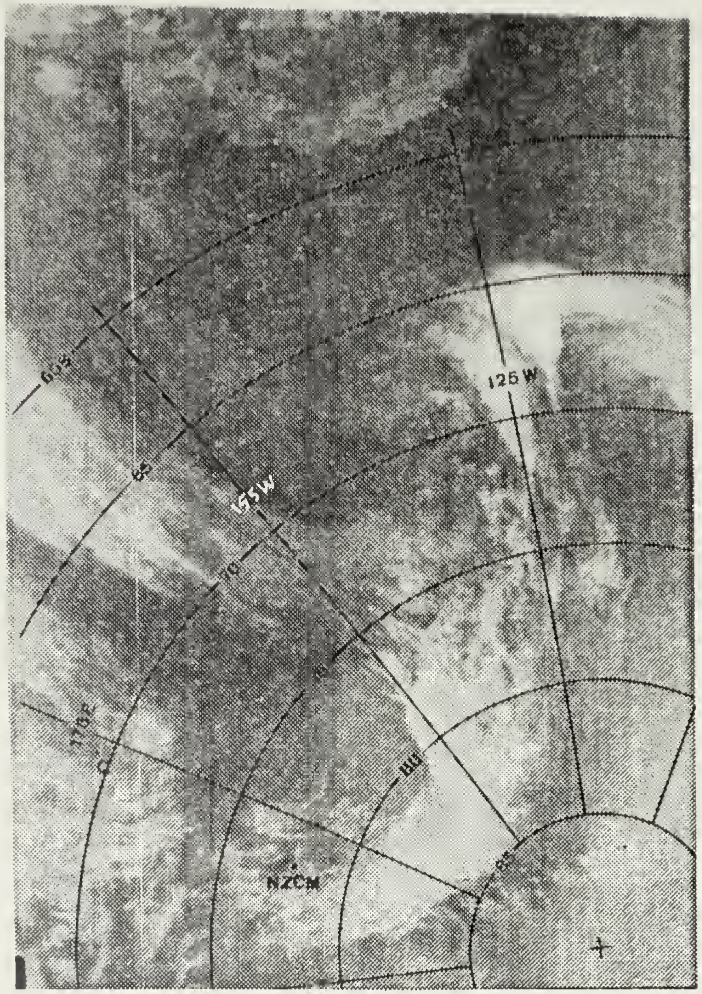


Figure 29. DMSP IR satellite observation, about 0300 GMT 11 January 1976.

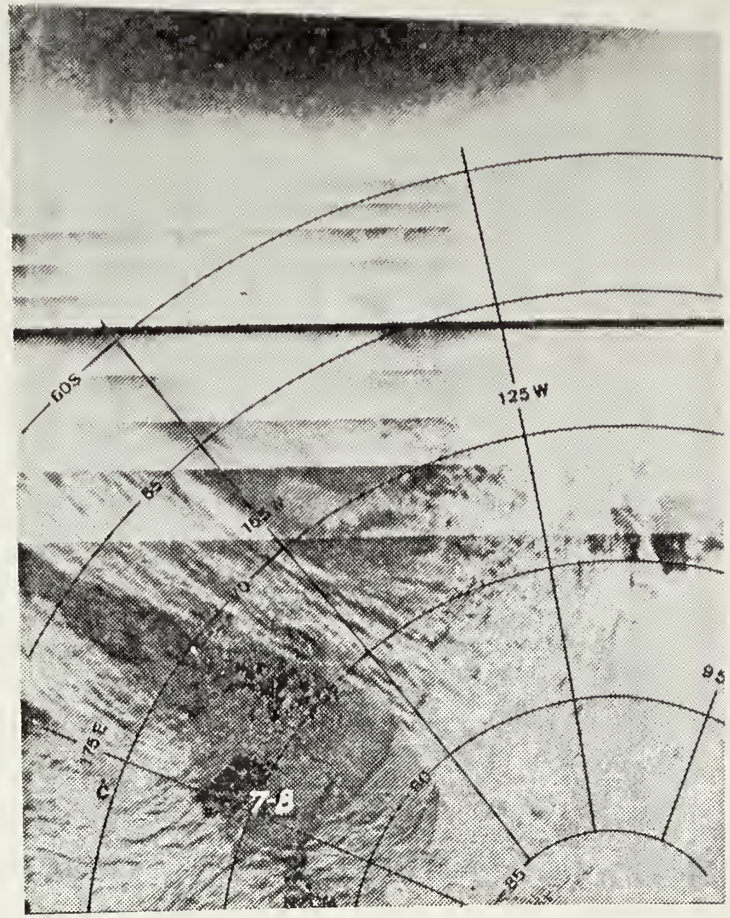


Figure 30. DMSP VIS satellite observation, about 0300 GMT 11 January 1976.

NR

observations showed intermittent periods of light snow and blowing snow; maximum winds were from 170 deg at 20 kt gusting to 40 kt, and visibility lowered to 5/8 mile. As observed in the vertical time cross section (Fig. 34) the major influx of low tropospheric moisture advection occurred beneath the 850 mb level with a maximum reading of 2.8 gm/kg below 950 mb.

8. 1200 GMT, 11 January 1976 Analyses (Figs. 31-33)

a. Upper Troposphere (400 mb: Fig. 31)

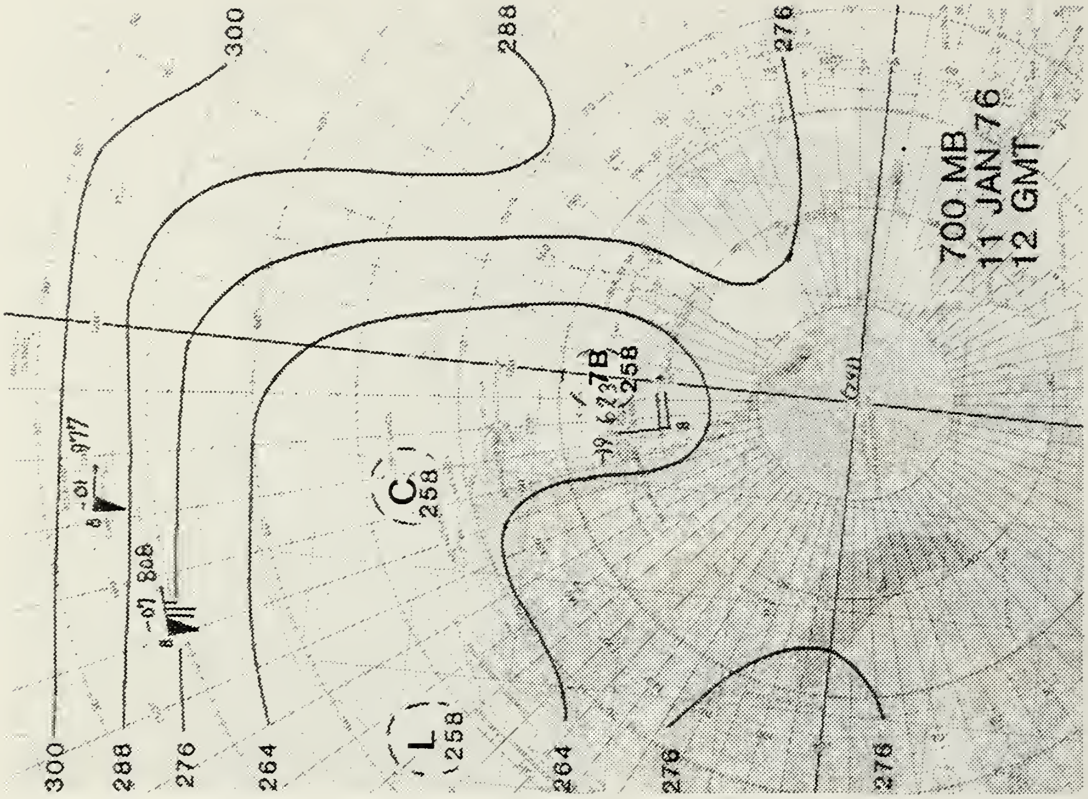
The ridge and associated circulation affecting McMurdo earlier in the day moved eastward. McMurdo then came under the influence of northerly flow. The 12-hour decreases of 130 gpm and 9^{o}C noted at the 400 mb level are indications that McMurdo once again is under the influence of a cold trough as the warmer anticyclonic circulation moved eastward. NOAA visual satellite imagery (Fig. 33) shows the major area of moisture intrusion to be east of the Ross Ice Shelf. However, there still remains a substantial meridional moisture advection pattern in middle and high latitudes as the satellite imagery shows.

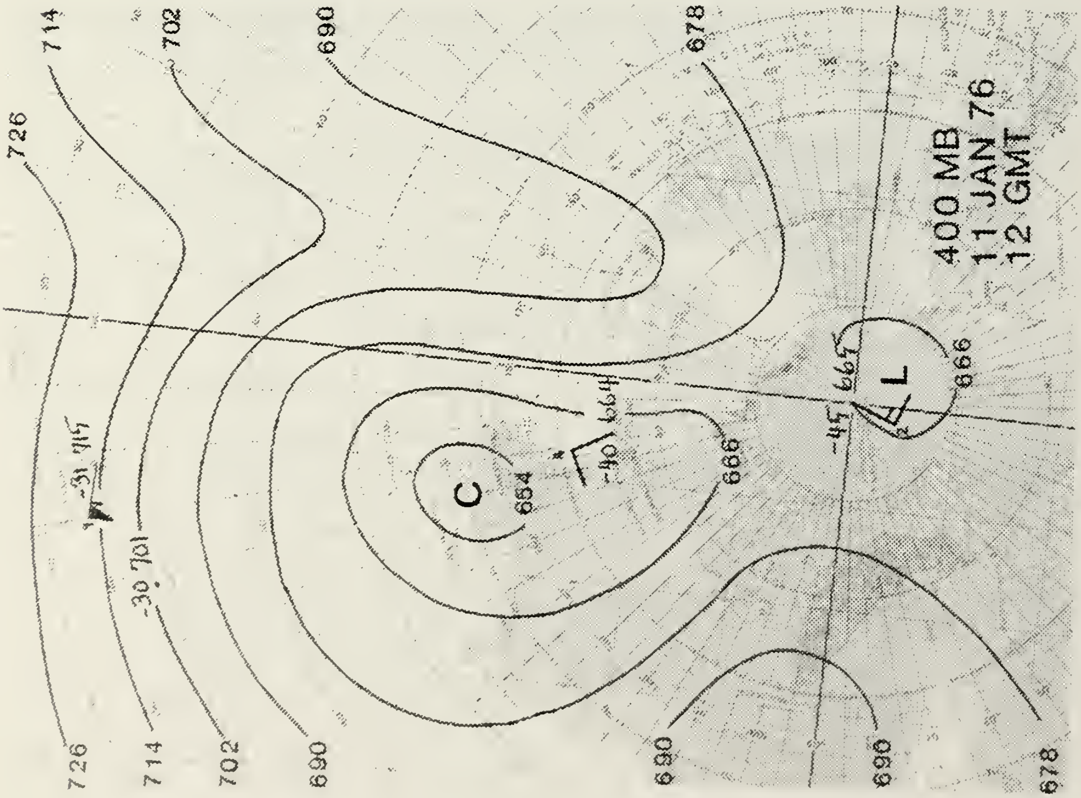
b. Lower Troposphere (700 mb: Fig. 32)

12-hr height falls of 53 gpm and a southerly wind indicates that vortex 7-B is now due east of McMurdo at 700 mb. The NOAA visual satellite imagery (Fig. 33) does not present any evidence of this circulation; it does however show that the brunt of the clouds of mid-latitude origin that entered the eastern Ross Ice Shelf have passed over or away from McMurdo, moving mostly south and east of the station.

C. NUMERICALLY-ANALYZED VS. SUBJECTIVELY-ANALYZED CIRCULATIONS

Fleet Numerical Weather Central has been numerically analyzing Southern Hemisphere constant pressure data in operational real time since


700 MB
11 JAN 76
12 GMT
300
288
276
264
258


400 MB
11 JAN 76
12 GMT
726
714
702
690
678
666
654

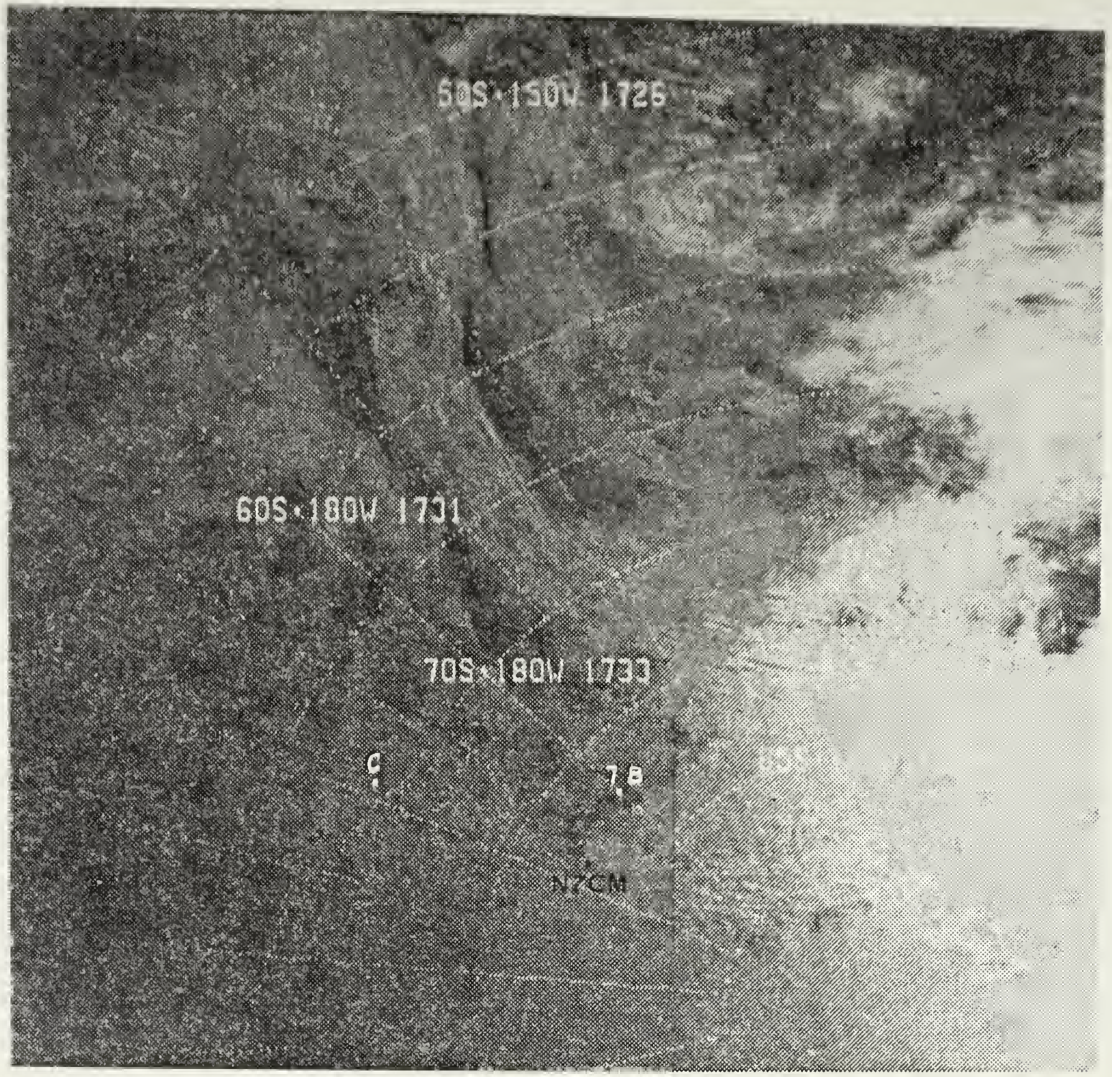


Figure 33. NOAA-4 PASS-5284 T-11 SEN-1 VIS 1/11/76 1740.

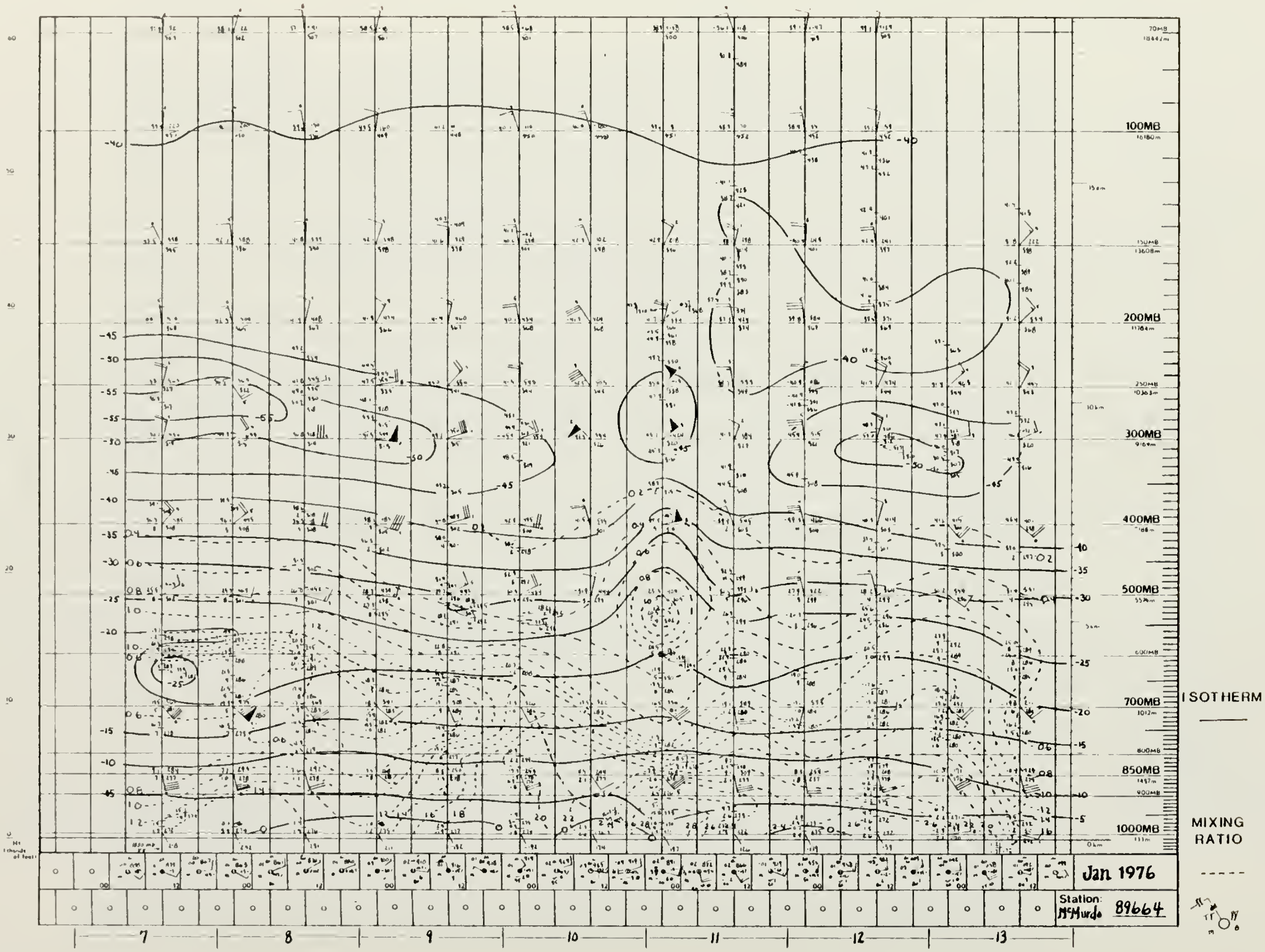


Figure 34. Vertical Time Cross-section, 7-13 January 1976.

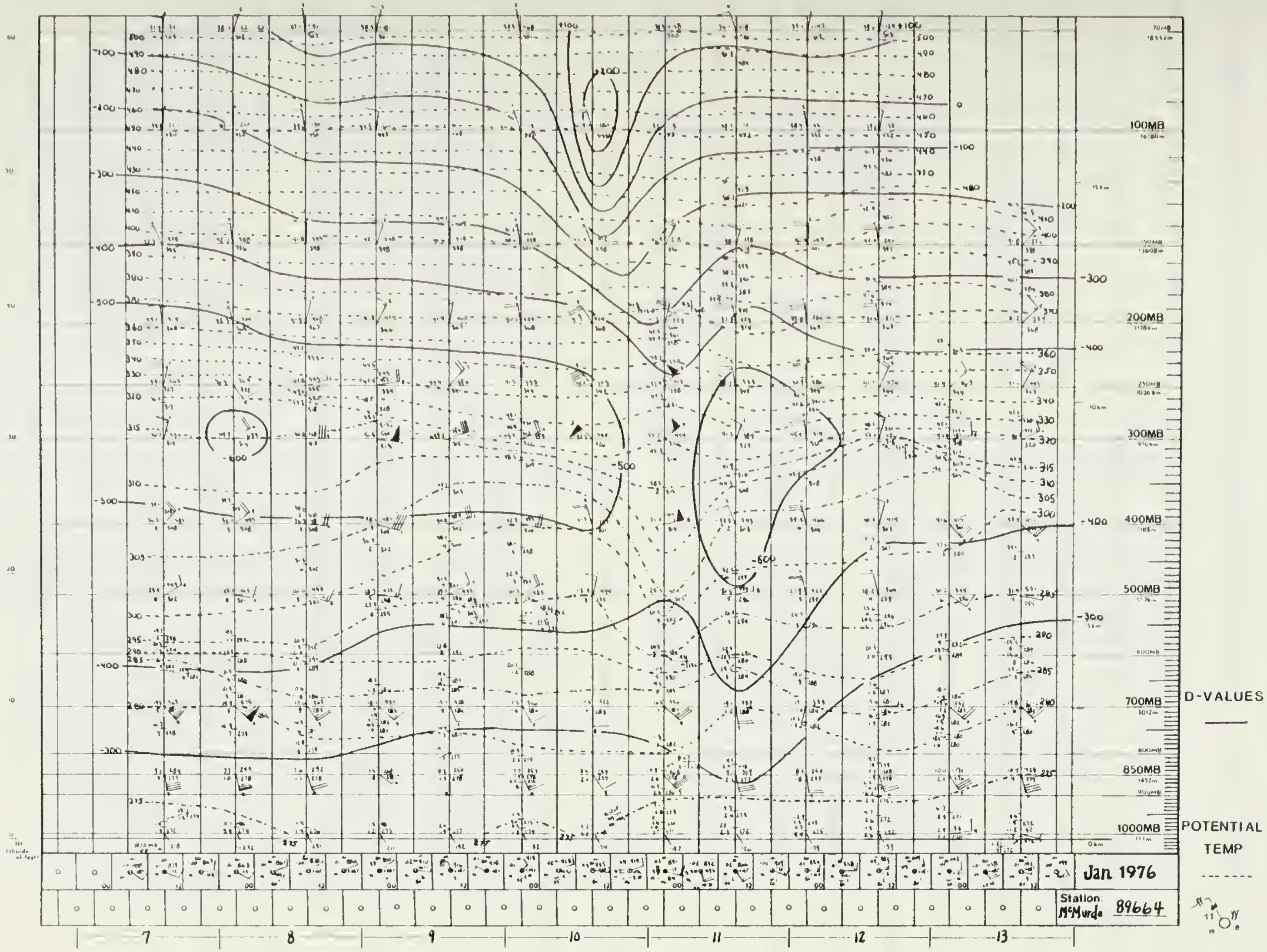


Figure 35. Vertical Time Cross-section, 7-13 January 1976.

April 1974, although the diagnostic products generally are not received by the McMurdo Weather Group. Analysis credibility is largely a function of data density; at best, conventional data are scarce. It is of interest to compare FNWC's final 700 mb analyses with those of the author for a selected area over and near Antarctica. The latter interpreted circulations from weather satellite imagery and (indirectly) from near-400 mb aircraft reports in addition to the conventional rawinsonde data. FNWC's objective upper-air analyses are a function of radiosonde data only over the Continent. However, the data base is enhanced by SIRS satellite sounding data which determine 1000/300 mb thicknesses over the water areas and indirectly enter at other levels through the computer processing in the mass structure model (Naval Weather Service Command, 1976). Further, the rawinsonde data available for analysis by FNWC are not necessarily the same as that available to this author.

It is readily seen in Fig. 36 that the two analyses differ markedly over and near the Continent throughout the case study period especially in relation to circulations associated with an influx of moist air over the Ross Sea and Western Antarctica. It would be expected that the analyses at other levels and prognoses derived therefrom would also show similar differences, although this does not imply such differences at every analysis time. The atmospheric circulations during the particular period under study are of great importance to the conduct of the ongoing scientific operations on the Ross Ice Shelf. As such, the need for satellite input to the operational numerical anlaysis over open water and snow/ice covered water and land areas is evident.

D. CONCLUSIONS

The synoptic weather pattern leading to the 11 January 1976 significant weather episode at McMurdo is that of a deepening long-wave trough as

Figure 36. Comparison of FNWC 700 mb analyses with those of the author. a) 8 Jan., b) 9 Jan., c) 10 Jan., d) 11 Jan. Heavy solid and dashed contours - author's analysis. Light solid lines - FNWC analysis.

it approached 160-170E. Concomitant with the deepening trough is a building ridge in the vicinity of 175E-170W. The building ridge is the mechanism by which a large area of meridional moisture advection entered the eastern Ross Sea and onto the Ross Ice Shelf. The ridge continued moving laterally eastward and by 00 GMT 11 January the moisture moving onto the Ross Ice Shelf was virtually cutoff as the major cloud bands impinged upon the Antarctic coast at about 140W. The moisture advected previously onto the Ross Sea was then circulated cyclonically over the Ross Ice Shelf thereby affecting McMurdo weather for only an 8-hour period. It is probable that with the moisture source maintained, cyclogenesis in the Ross Sea would have continued and a major storm would have resulted.

This case study has demonstrated that synoptic scale moisture advection sources and its southerly extent can be qualitatively determined by utilizing satellite imagery. On the mesoscale, orographic lifting of clouds and subsequent cloud patterns (i.e. IR cloud plumes) can be used to estimate wind direction. Through basic topographical familiarity, adiabatically dried air formed by air descending from the high plateau region to the low ice shelf may be observed on satellite imagery of sufficient resolution as a tongue of clear air invading a previously existing cloud mass. Hence the identification of mesoscale anticyclonic vortices in the vicinity of the topographic discontinuities of the plateau/ice shelf are readily made.

The importance and limitations of the DMSP IR and visual modes are to be noted. IR imagery was used to qualitatively describe upper-level wind direction by correlating the striations of bright cloud returns with wind directions. The limitations arise in that misinterpretation can

result when top-cloud temperature returns from striations, say at 500 mb, are assumed to exist for other levels as well, say 400 mb or 600 mb. This is the case in the 00 GMT, 11 January 1976 400 mb analysis. Cloud striations in Fig. 29 indicate southeasterly winds, yet northeasterly winds are actually observed. It is therefore essential that analysis of any vertical soundings be made in order to resolve this dilemma. In this case the vertical time cross section (Fig. 34) shows that a maximum mixing ratio center at 550 mb and southeasterly winds at 500 mb and below are observed.

It is obviously necessary that all available data be assimilated in all dimensions and time so that a representative depiction of atmospheric events can be made.

VIII. CASE STUDY OF THE ATMOSPHERIC EVENTS ASSOCIATED WITH THE 25-26 DECEMBER 1975 SIGNIFICANT WEATHER SEQUENCE AT McMURDO STATION, ANTARCTICA (Figs. 37-68)

A. INTRODUCTION

The 25-26 December 1975 significant weather sequence is a prime example of warm, moist air intrusion into the Ross Ice Shelf area associated with a building ridge over West Antarctica. Although the most pronounced weather experienced at McMurdo during this sequence consisted of a reduction in visibility to one mile in snow between 0800 and 1200 GMT on 25 December 1975, much of the Ross Ice Shelf appeared to have experienced a four-to-five-day extended period of snowfall. With added emphasis on the conduct of research on the Ross Ice Shelf in recent years, an extended period of cloudiness and intermittent snowfall holds considerable importance to both field parties and support personnel.

As noted on the time cross-sections (Figs. 66 and 67) for McMurdo, intermittent periods of snowfall were observed from 20-22 December 1975. Satellite imagery for these days indicates cloudiness confined to the western Ross Ice Shelf. Since this snowfall did not appear to be directly associated with synoptic scale events and was localized, it does not warrant detailed investigation.

The case study starts with events on 22 December 1975.

B. CASE STUDY ANALYSIS (00 GMT 22 December - 12 GMT 25 December 1975)

1. 0000 GMT 22 December 1975 Analyses (Figs. 37-40)

a. Upper Troposphere (400 mb: Fig. 37)

Aircraft reports between McMurdo, Dome CHARLIE, and South Pole indicate the existence of a cyclonic vortex A estimated to be

about five degrees latitude west-northwest of McMurdo and a second cyclonic vortex (4-B) about four degrees latitude southeast of Vostok. A third cyclonic vortex (4-C), based on the 20 kt grid southeasterly wind at South Pole is analyzed approximately two deg lat to the grid northeast of Pole. Because of the importance of the tilt associated with vortex A in the case study, the relative positions of the vortex circulations at 700 mb and 400 mb are discussed separately at each level, hence vortex A will be labeled as 4-A and 7-A.

DMSP IR satellite imagery (Fig. 39) indicates middle cloud tops in the vicinity of McMurdo. The 0600 GMT McMurdo surface observation which is closest in time to the satellite imagery, estimated cloud bases as 7000 ft with light snow precipitating. Bright returns from orographically lifted air in the vicinity of 71S 160E indicates westerly wind flow in that area. Note the sharp boundary on the western edge of the cirrus cloud plume and the decrease and diffusion of the cloud brightness to the east. An anticyclonic trajectory of meridional moisture advection extending to middle/high tropospheric levels is observed on the IR and visual imagery near and east of 155W from 70S southward to the Antarctic coast line.

b. Lower Troposphere (700 mb: Fig. 38)

Both DMSP IR and visual satellite imagery (Figs. 39 and 40) show some cyclonic curvature in cloud striations just north of McMurdo. This appears to be the eastern extent of the low level cyclonic vortex (7-A). Low troposphere clouds with apparent anticyclonic curvature are noted on the visual imagery, six deg lat southwest of McMurdo over the polar plateau. DMSP IR satellite imagery shows some light gray striations oriented in a northeast to southwest direction indicating that some

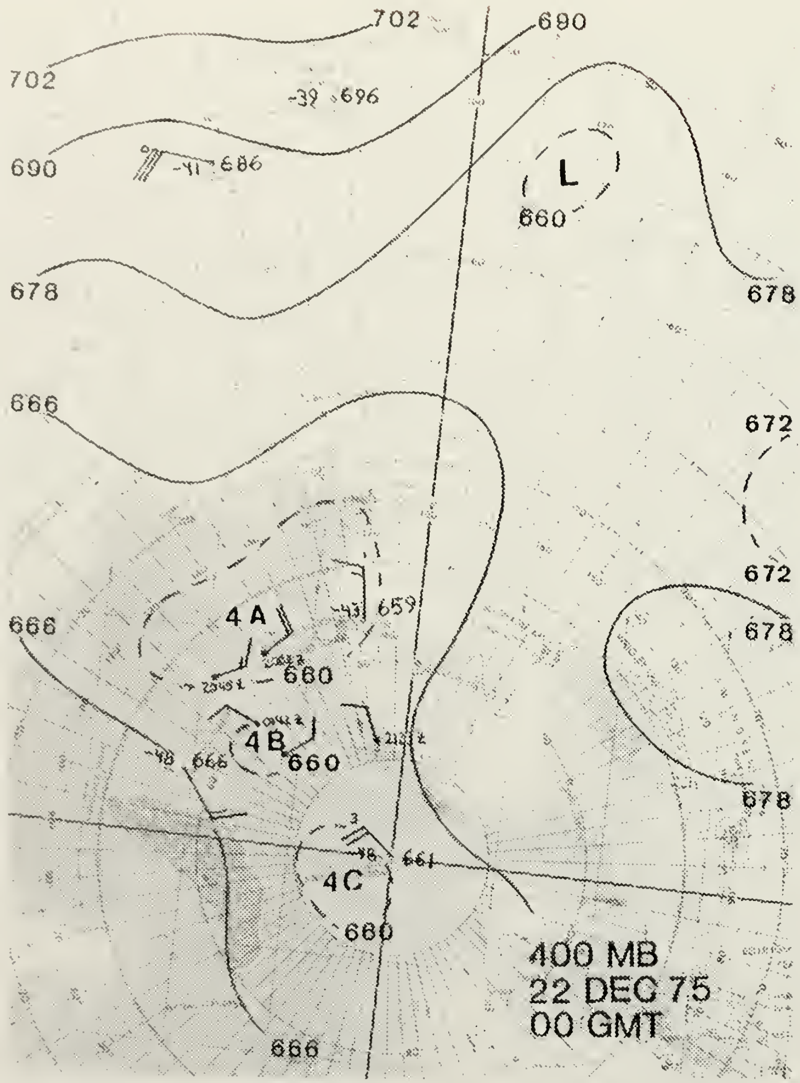


Figure 37

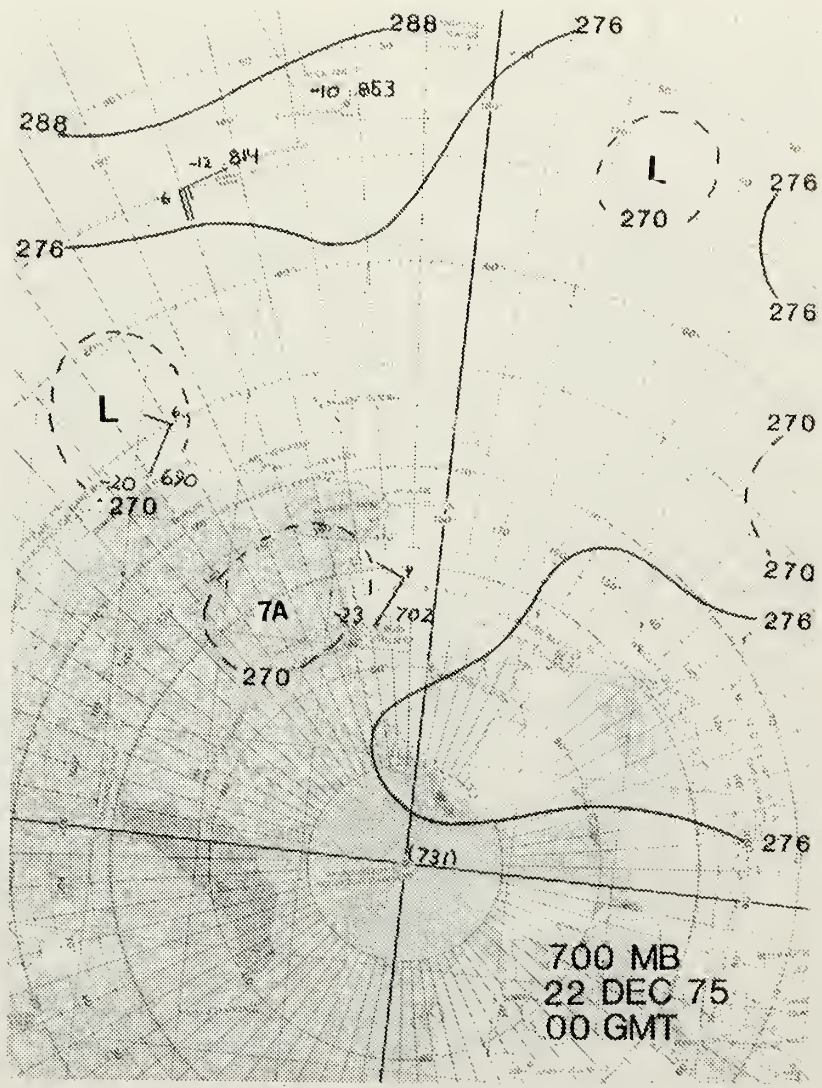


Figure 38

Figure 39. DMSP IR satellite observation, about 0500 GMT 22 December 1975.

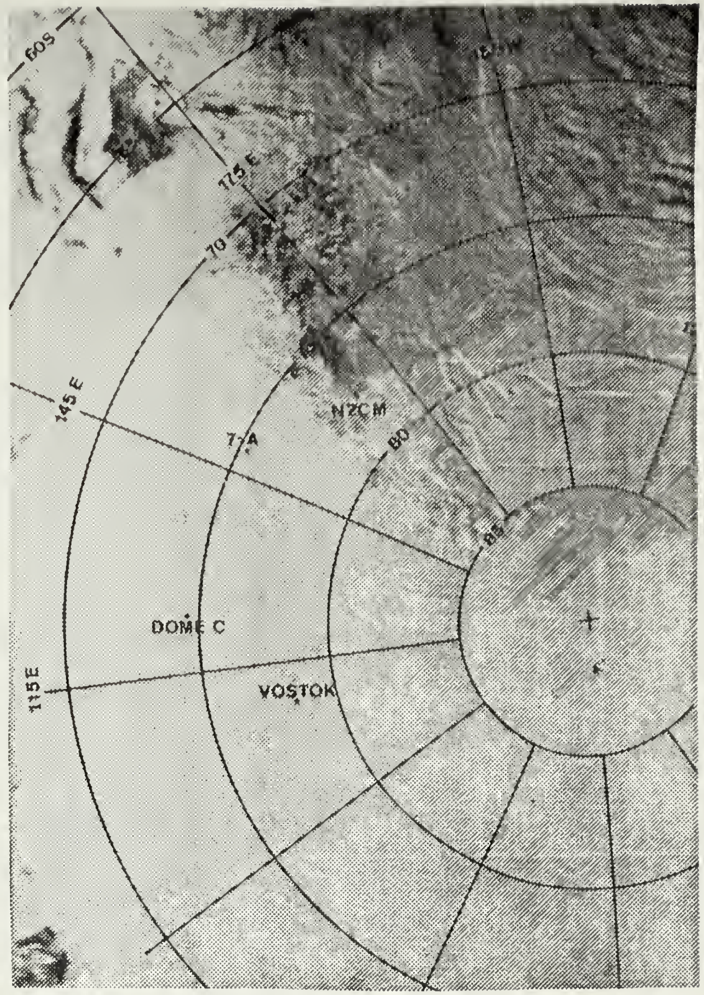


Figure 40. DMSP VIS satellite observation, about 0500 GMT 22 December 1975.

orographic lifting is occurring in that area. This feature is represented in the 700 mb analysis as anticyclonic flow with an associated ridge extending from the western part of West Antarctica over the Trans-Antarctic Range.

2. 1200 GMT 22 December 1975 Analyses (Figs. 41-44)

a. Upper Troposphere (400 mb: Fig. 41)

NOAA visual satellite imagery (Fig. 43) shows cyclonic cloud curvature associated with a broad trough northeast of McMurdo extending to a weak cold core eddy in the vicinity of 53S 160W four hours after map time. Another spiralling, rather complex eddy is located in the vicinity of 65S 140W. The structure of this eddy has similarities to the comma shaped cloud masses associated with positive vorticity advection maxima (PVA MAX) as described in Project FAMOS Research Report 4-67 (Bittner, 1967). Fig. 44 shows a nephanalyses depicting the structure of the eddy and probable air flow. As noted on the nephanalysis, the PVA MAX cloud mass bulges towards the southwest indicating its probable direction of movement. It is the southward advection on the western perimeter of the PVA MAX which is transporting moisture into the eastern Ross Sea area. The 30 gpm and 2°C drop as well as the reduction of wind speed at 400 mb (Fig. 66) in the past 12 hours indicates that cold core vortex 4-A is drifting eastward toward McMurdo. Vortex 4-B near Pole Station is drifting grid east as the temperature and 400 mb height increased 1°C and 10 gpm, respectively, in the past 12 hours.

b. Lower Troposphere (700 mb: Fig. 42)

Vortex 7-A appears to be over McMurdo at this time as evidenced by nearly calm winds and a 21 gpm decrease in 700 mb height in the past 12 hours. Ridging from West Antarctica continues to build over

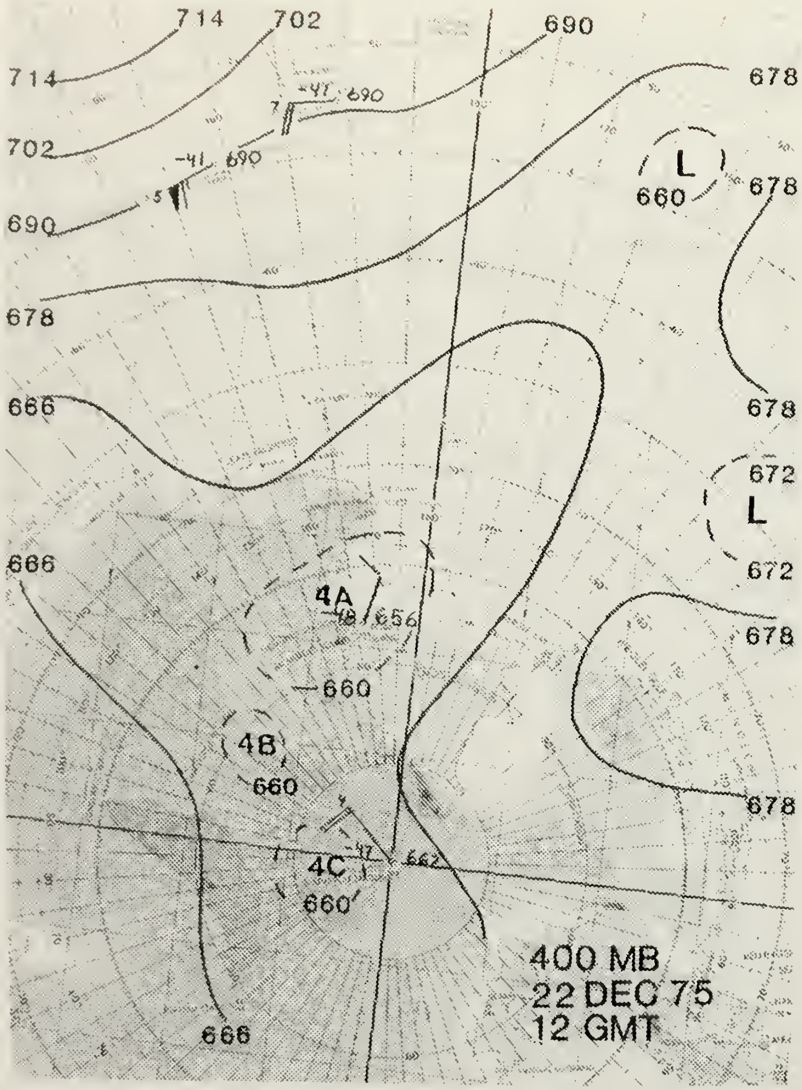


Figure 41

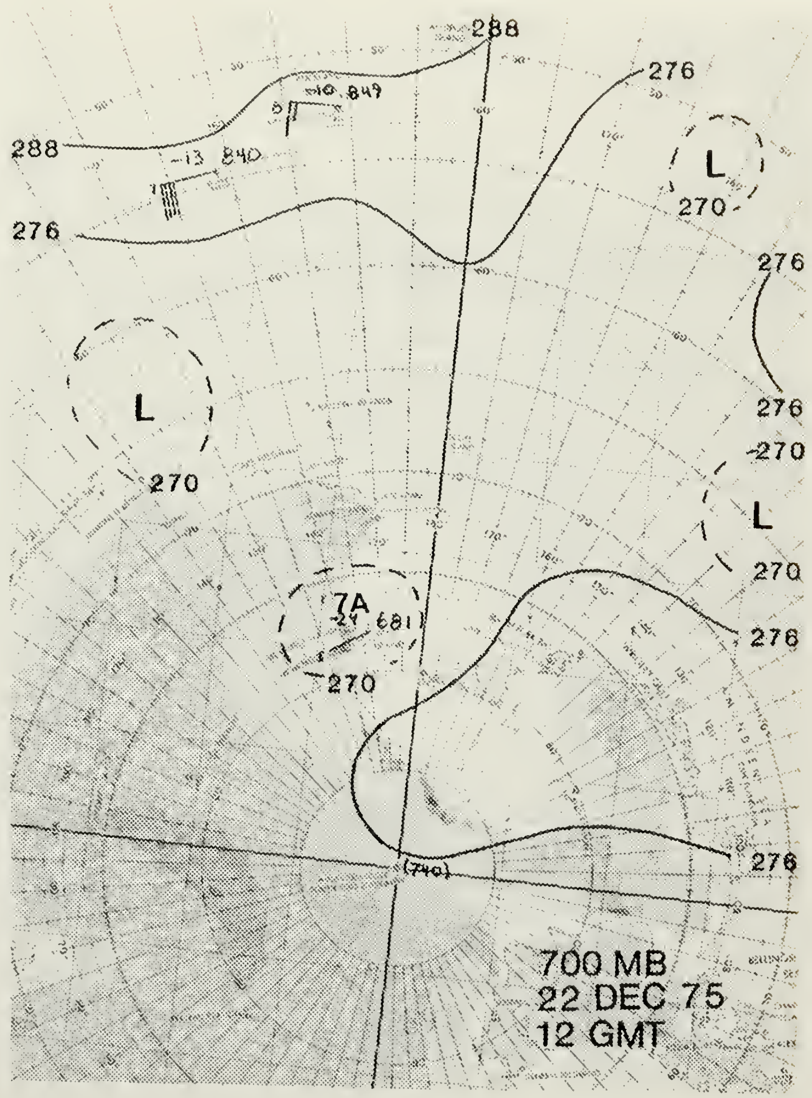


Figure 42

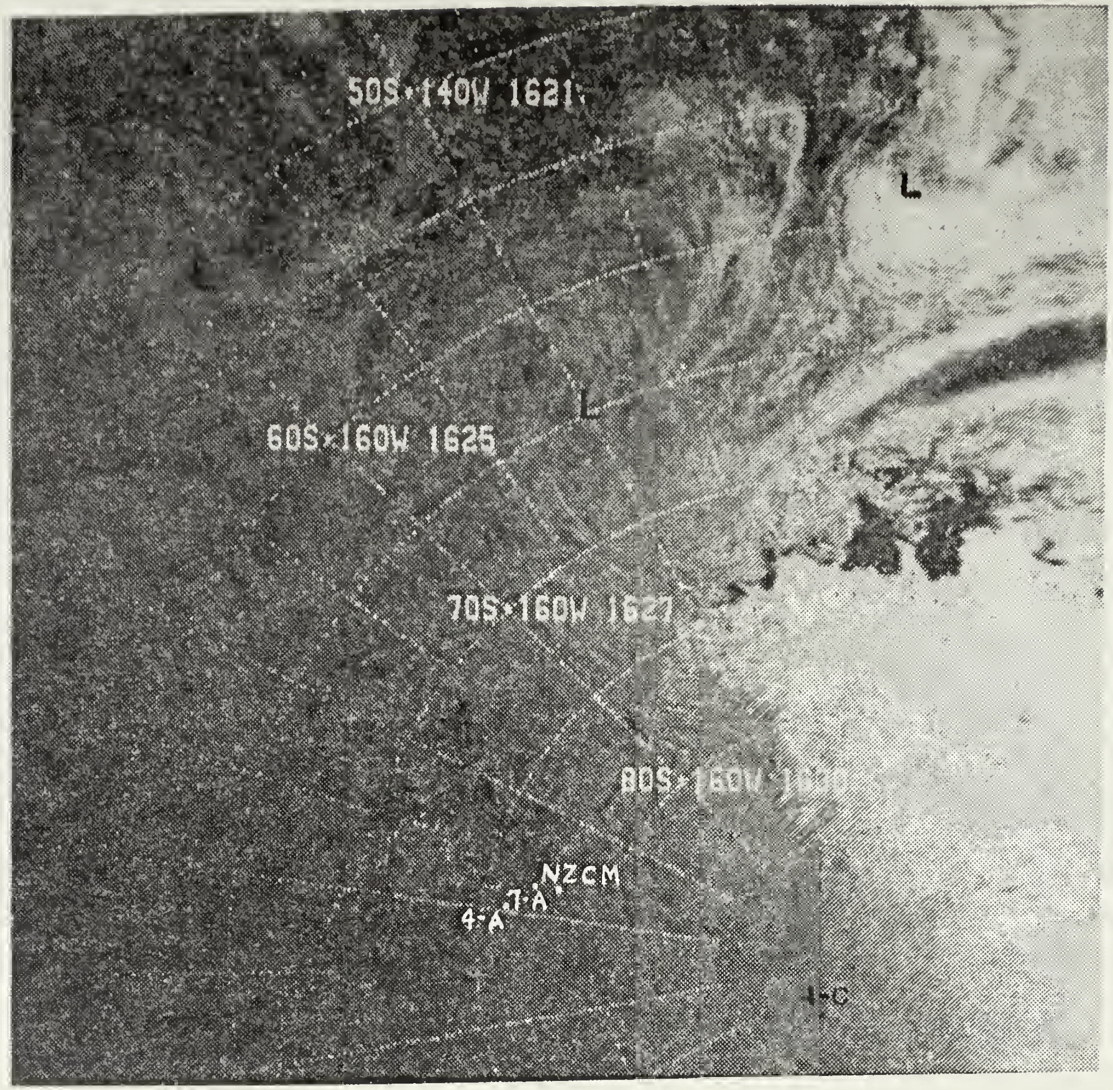


Figure 43. NOAA-4 PASS-5033 T-10 SEN-1 VIS 12/22/75 1634.

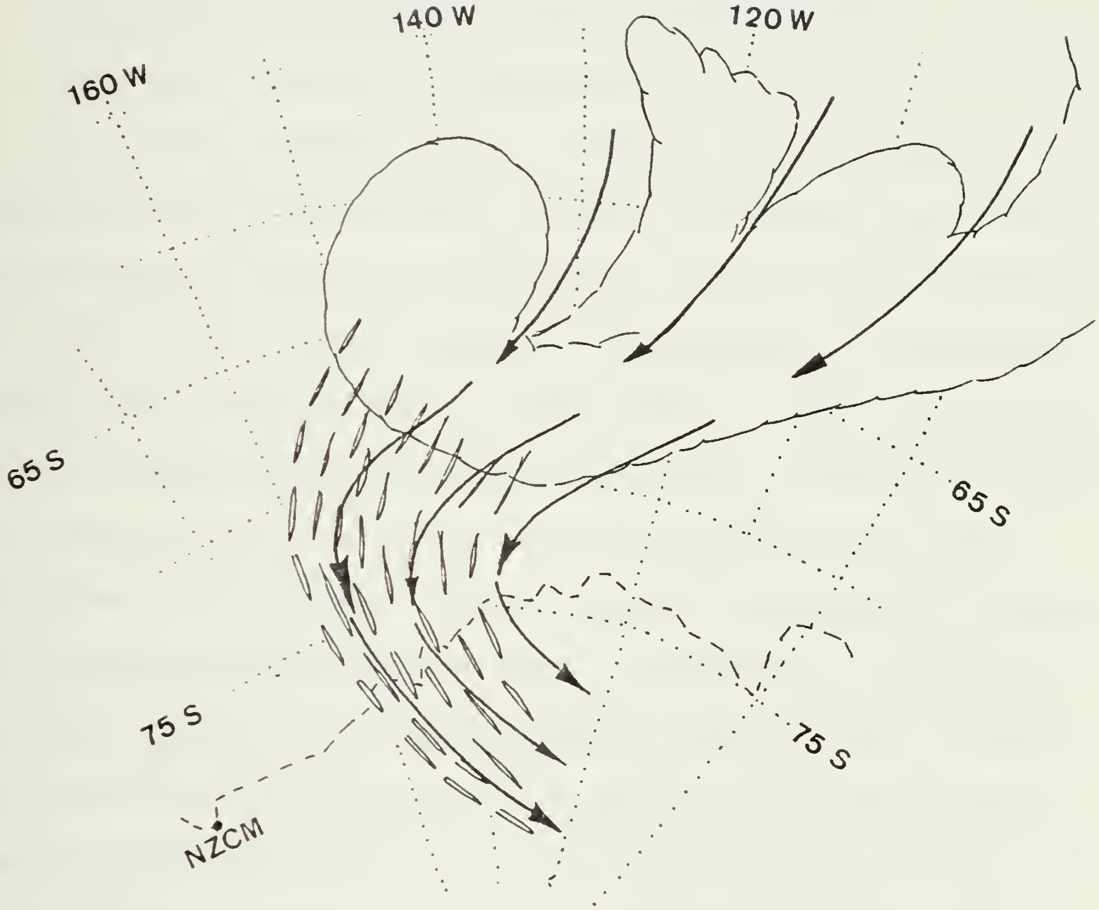


Figure 44. Nephanalysis of PVA-type cloud mass.

the polar plateau. NOAA visual satellite imagery (Fig. 43) shows the western extent of the major moisture intrusion to be in the vicinity of the Trans-Antarctic Mountain Range at 180 deg. Further evidence of orographic effects, namely downslope flow, is evidenced by the cloudless coastline in the vicinity of 75S, 135W to 110W.

3. <u>0000 GMT, 23 December 1975, Analyses (Figs. 45-48)</u>

a. Upper Troposphere (400 mb: Fig. 45)

DMSP IR imagery (Fig. 47) presents a rather remarkable figure yielding detailed cloud structures in nearly all areas of the analysis. On the northwestern edge of the imagery just south of Dumont D'Urville (67S 140E) onshore flow and orographic lifting results in bright anticyclonic cloud situations over the polar plateau. Continuing south and east the striations gradually lessen in brightness, disappear, and suddenly reappear with a very distinct western boundary near 72S 162E. This is where the relatively moist air, possibly accompanied by blowing snow, impinges upon an orographic feature and results in a high level cloud plume tailing off (becoming narrower) toward the east. Aircraft reports from Navy LC-130 aircraft at 24,000 feet (near 400 mb level) observed winds west-southwest at 30 kt and west at 60 kt at 70S and 73S, respectively, near the plume area five hours before the satellite observation.

Cyclonic cloud curvature is observed on the IR imagery in the vicinity of 57S 165W. This has been analyzed as the northern extent of a 400 mb trough oriented in a north-northeasterly direction from McMurdo. The bright meridionally oriented cloud return extends southward from the northern source region into the eastern Ross Sea and Shelf area. The bright, rather narrow streams of cloudiness begin to diverge at about

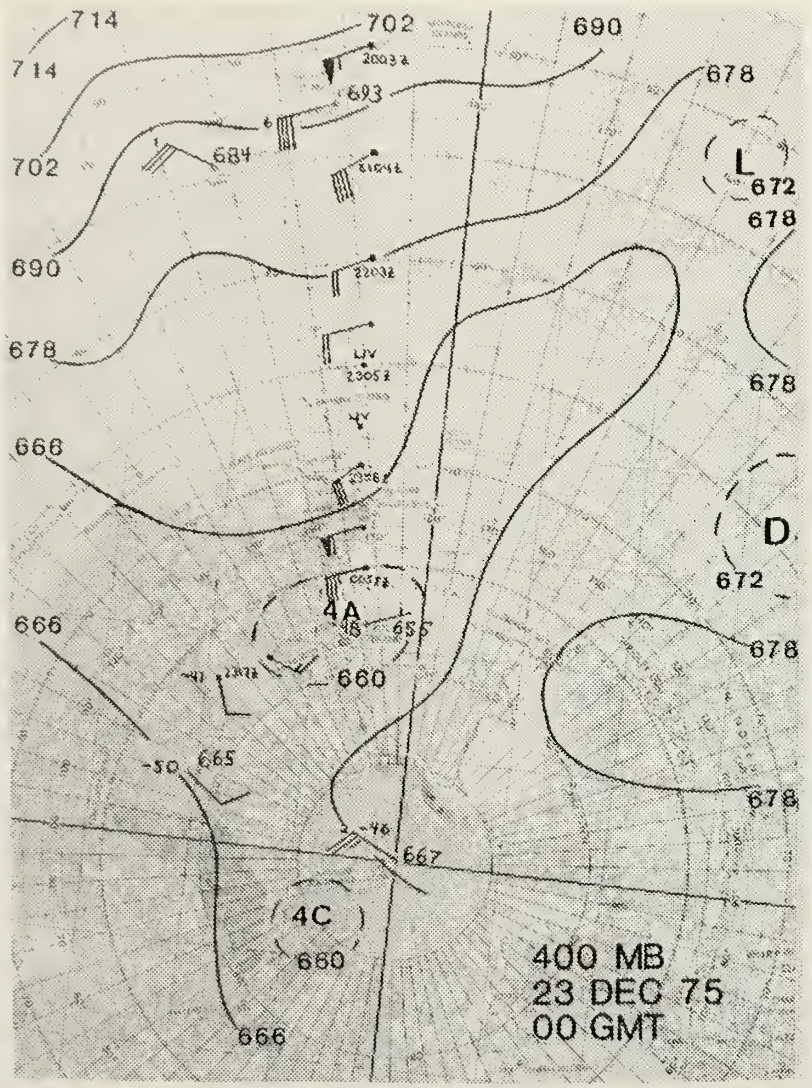


Figure 45

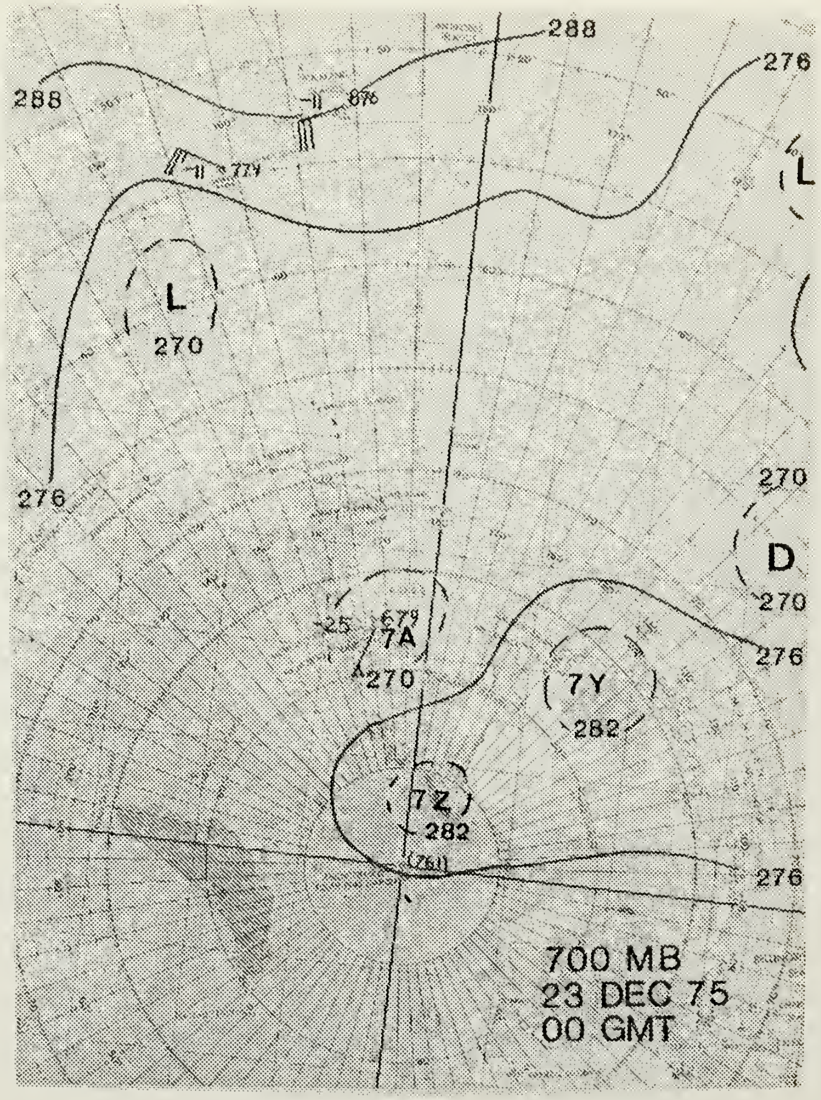


Figure 46

Figure 47. DMSP IR satellite observation, about 0500 GMT 23 December 1975.

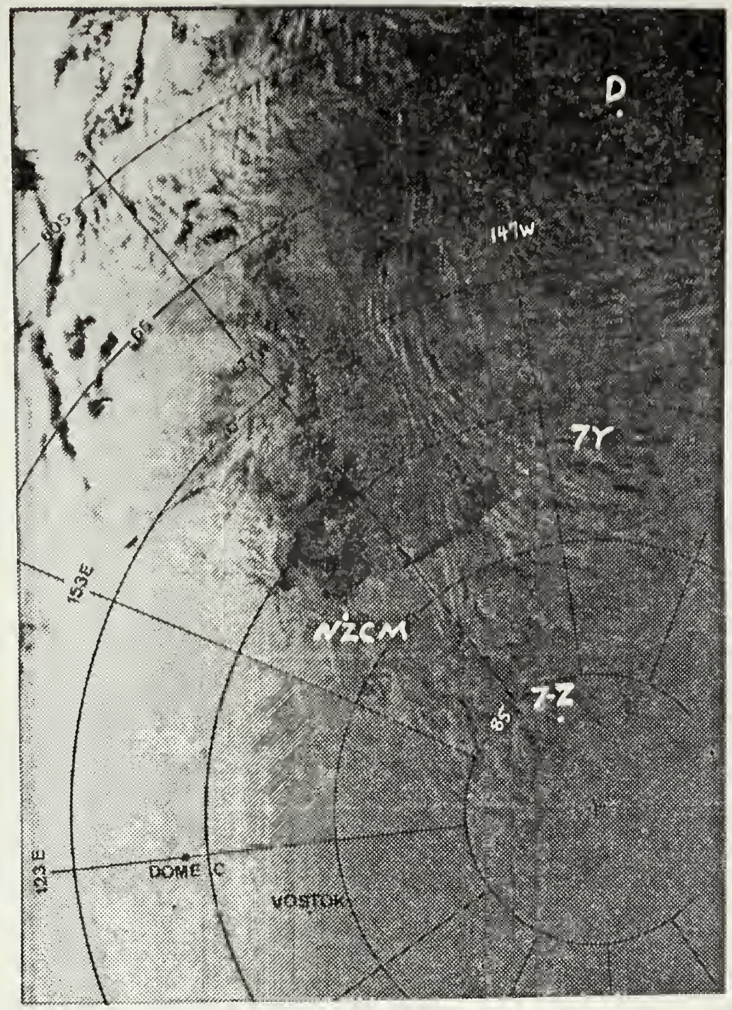


Figure 48. DMSP VIS satellite observation, about 0500 GMT 23 December 1975.

70S. One branch of moisture moves south of McMurdo and is orographically lifted over the Trans-Antarctic Mountain Range forming bright cloud plumes from about 84S to 86S and then turning anticyclonically towards South Pole Station. The South Pole 400 mb observation shows a grid east-southeast wind at 25 kt which agrees well with the cloud striations observed near Pole Station. The second branch of the observed diverging cloud bands, along with some moisture advection from the southeast side of cyclonic vortex D located in the vicinity of 64S 136W, results in bright anticyclonic curved cloud returns in the vicinity of 76-80S, 150-135W.

Aircraft reports on the New Zealand to McMurdo flight track allows considerable detail in the contour analysis; the reports on the Dome Charlie flight track agree with the apparent cyclonic curvature of the cloud patterns there and along with the McMurdo observation places cyclonic vortex 4-A about two degrees latitude west-northeast of the station.

b. Lower Troposphere (700 mb: Fig. 46)

Cold core vortex 7-A has moved slightly east of McMurdo as evidenced by a 5 kt southwesterly wind. DMSP visual satellite imagery (Fig. 48) shows the two areas of anticyclonic curvature, previously discussed from the IR imagery in greater detail. Anticyclonic vortex centers are located at about 87S 165W (7-Z) and 77S 140W (7-Y). The 700 mb vortex D is analyzed in the same position as its 400 mb counterpart, in an area of broad cyclonic cloud curvature.

Note the ice in the center of the Ross Sea on the visual imagery; the ice appears similar to open cell cumulus clouds. The area appears free of low cloud but there is evidence of high cirrus on both

the visual and infrared images. Because the temperature of the ice surface and surrounding water are approximately the same, the ice feature is not visible in the IR imagery (Fig. 47).

4. <u>1200 GMT, 23 December 1975 Analyses (Figs. 49-51)</u>

a. Upper Troposphere (400 mb: Fig. 49)

The ridge from West Antarctica continues to build as evidenced by a 12-hour 50 gpm height and $2^{o}C$ temperature rise at South Pole, and the continued advance of clouds toward grid northeast relative to Pole. NOAA visual satellite imagery (Fig. 51) shows vortex D centered in the vicinity of 66S 143W. The remaining circulation features are maintained by continuity.

b. Lower Troposphere (700 mb: Fig. 50)

With the McMurdo sounding missing and no significant changes observed in the NOAA satellite imagery (Fig. 51), the 700 mb analysis reflects simple continuity from the 0000 GMT analysis.

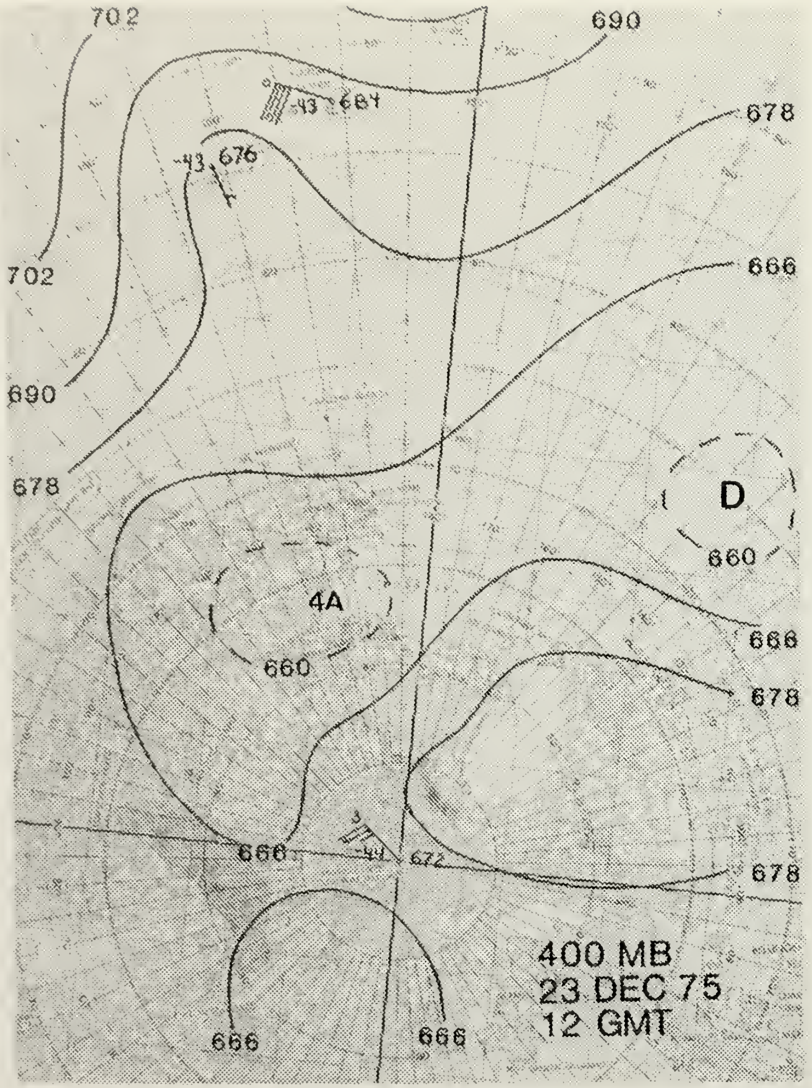
5. <u>0000 GMT, 24 December 1975 Analyses (Figs. 52-55)</u>

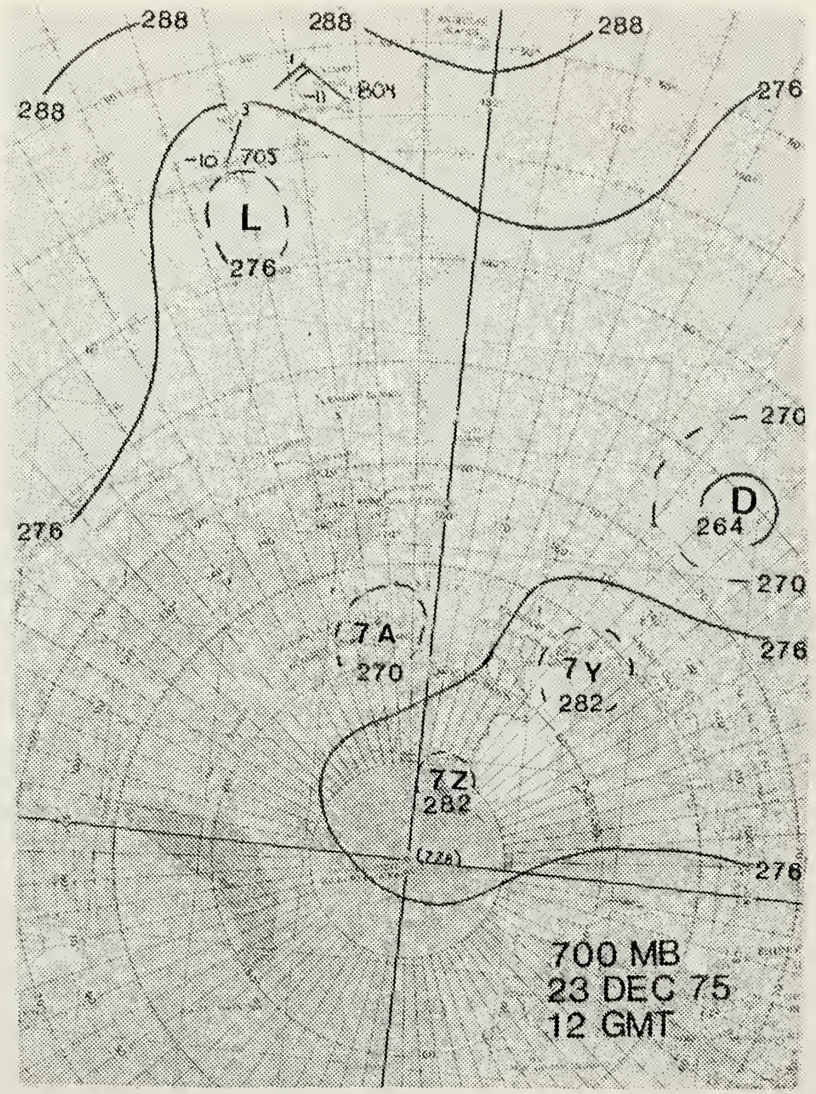
a. Upper Troposphere (400 mb: Fig. 52)

DMSP IR satellite imagery (Fig. 54) shows vortex D has moved southward to about 67S 144W. Brightness returns from higher clouds in the DMSP imagery indicate that substantial moisture is now being advected onto the Ross Ice Shelf and over the polar plateau. The major thrust of the moisture intrusion remains approximately three degrees of latitude east and south of McMurdo.

Vortex 4-A remains west of McMurdo. Mostly light westerly winds and low mixing ratios prevail in the troposphere above the surface layer (Fig. 66), placing McMurdo under broken skies.

The bright anticyclonically curved striations resulting from orographically lifted air remains an excellent method of tracing wind


400 MB
23 DEC 75
12 GMT
702
690
678
666
660
4A
D
676
684
672


700 MB
23 DEC 75
12 GMT
288
276
270
264
282
L
D
7A
7Y
7Z
705
804

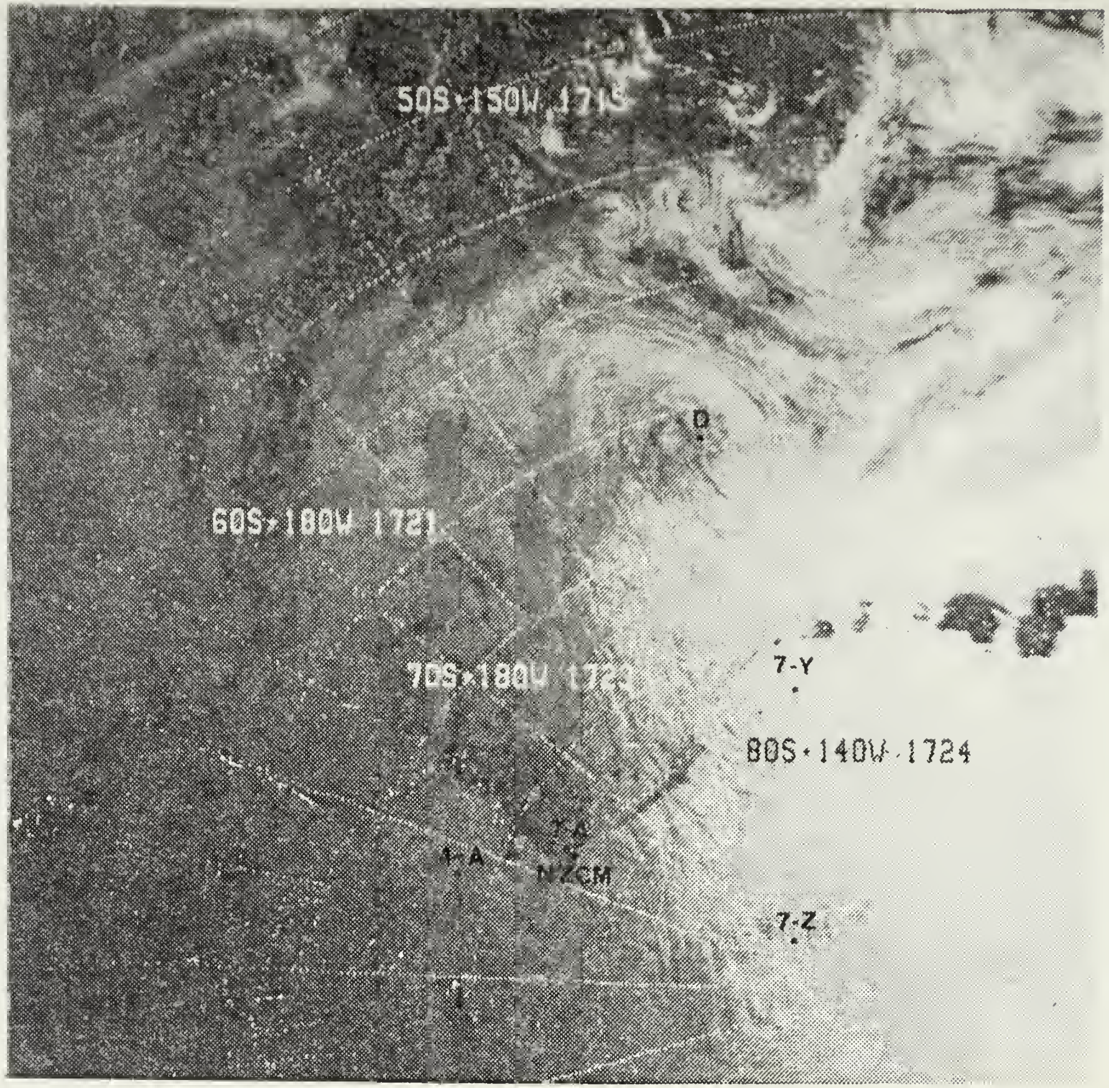


Figure 51. NOAA-4 PASS-5046 T-11 SEN-1 VIS 12/23/75 1729.

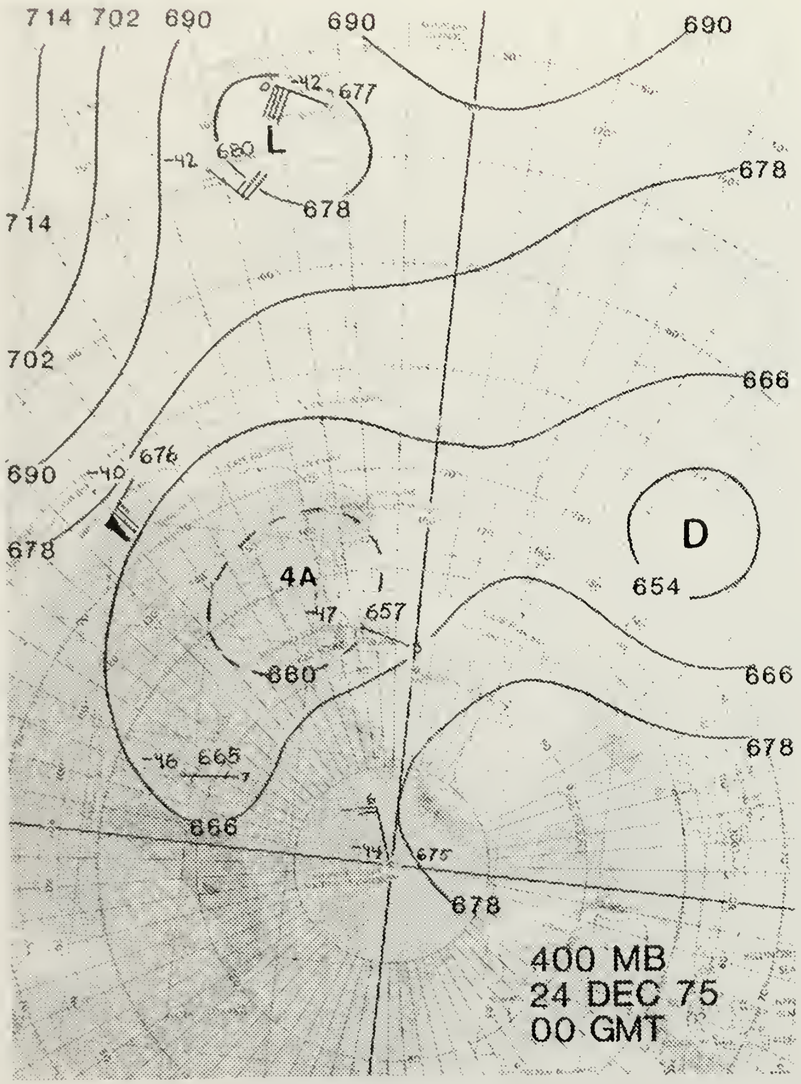


Figure 52

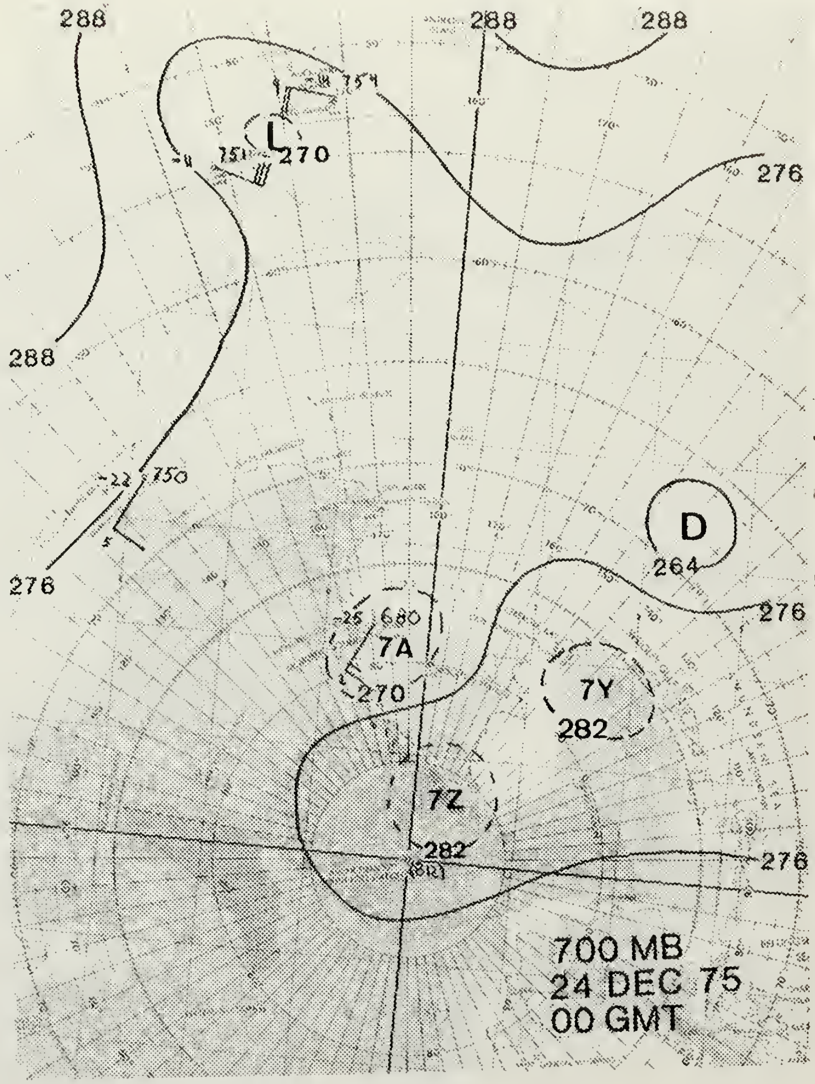


Figure 53

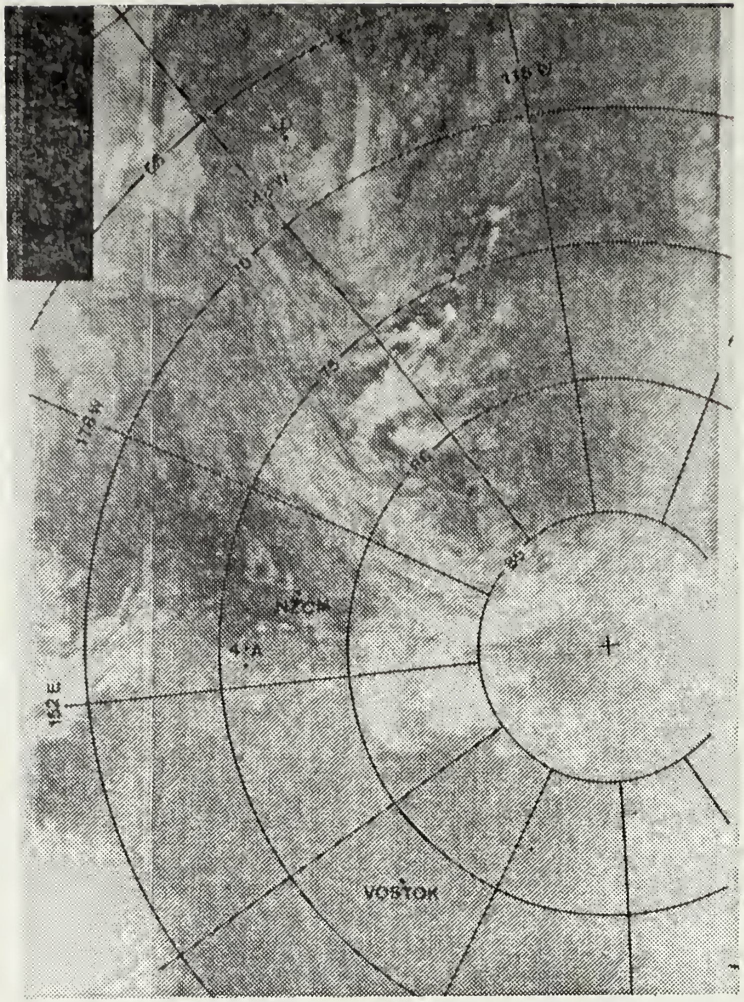


Figure 54. DMSP IR satellite observation, about 0400 GMT 24 December 1975.

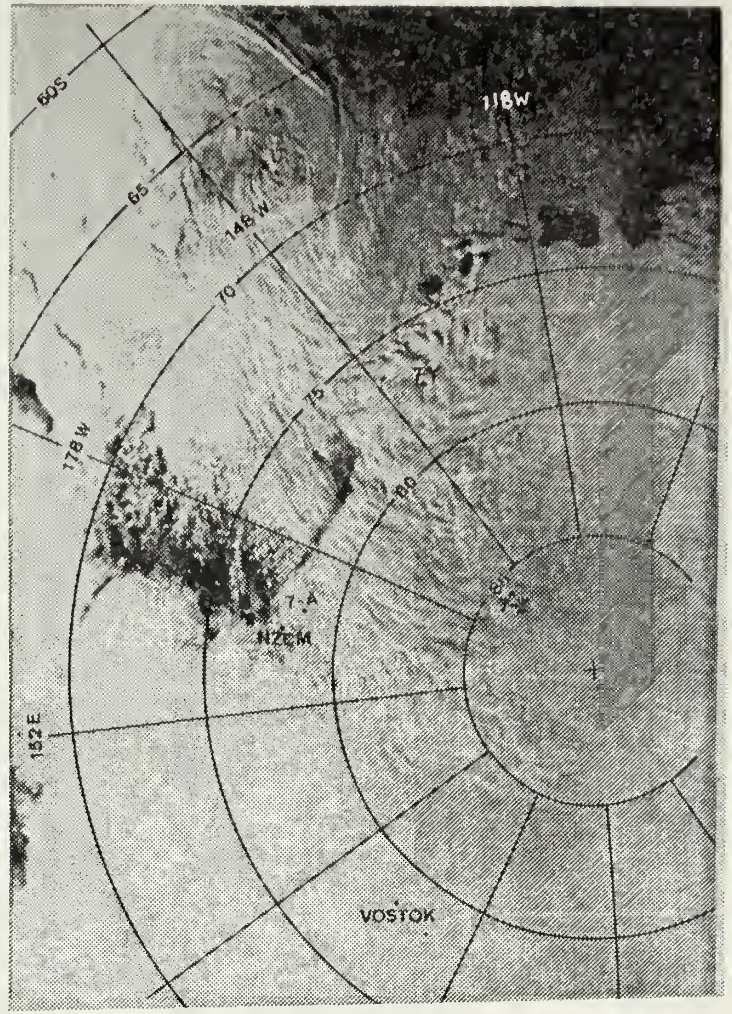


Figure 55. DMSP VIS satellite observation, about 0400 GMT 24 December 1975.

direction over the polar plateau between McMurdo and South Pole. Bright cloud plumes in the vicinity of 76S 135-145W indicate a change in wind direction in that area. The sharp boundaries on the cloud plumes are now on the eastern side of the plumes indicating winds in that region are easterly.

b. Lower Troposphere (700 mb: Fig. 53)

An increasing southwesterly wind at McMurdo indicates that vortex 7-A is located east of the station. The combination of southwesterly flow at McMurdo and easterly components to the south, results in moisture being orographically lifted in the latter area, as evidenced by clouds in the DMSP visual (Fig. 55) and IR satellite imagery (Fig. 54). As long as the 700 mb winds have a westerly component, McMurdo will not experience any significant precipitation from low level moisture sources. Anticyclonic vortex (7-Z) has remained essentially stationary promoting a further influx of moisture toward grid northeast relative to Pole. Anticyclonic vortex (7-Y) appears to have elongated along an east-west axis as indicated by the cloud plumes on the IR imagery. Considerable moisture advection onto the Ross Ice Shelf continues as vortex D approaches the Antarctic coastline.

6. <u>1200 GMT, 24 December 1975 Analyses (Figs. 56-58)</u>

a. Upper Troposphere (400 mb: Fig. 56)

Continued building of the ridge from West Antarctica is evidenced by a 24-hour 60 gpm height rise at South Pole. NOAA visual satellite imagery (Fig. 58) shows the moisture intrusion near the ridge line extending to 120E at the near pole latitude. Although there was no sounding available at McMurdo, cloud striations in that area are oriented so as to indicate the presence of a northeasterly wind. Moisture advection

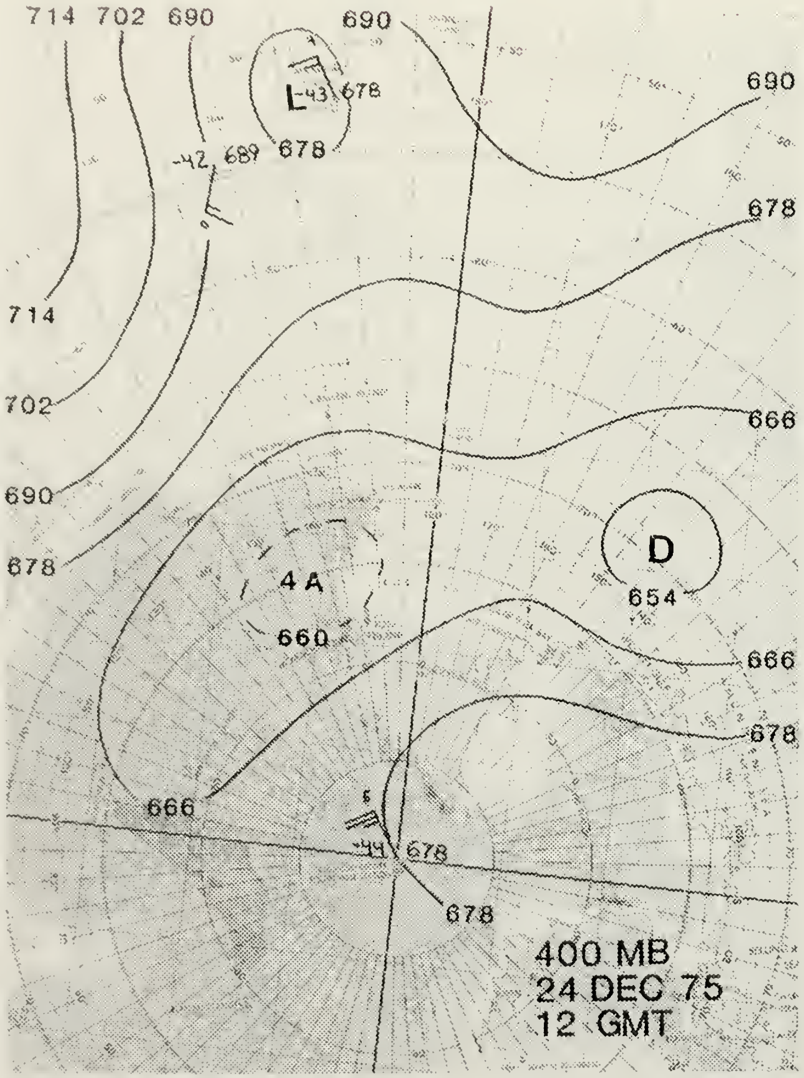


Figure 56

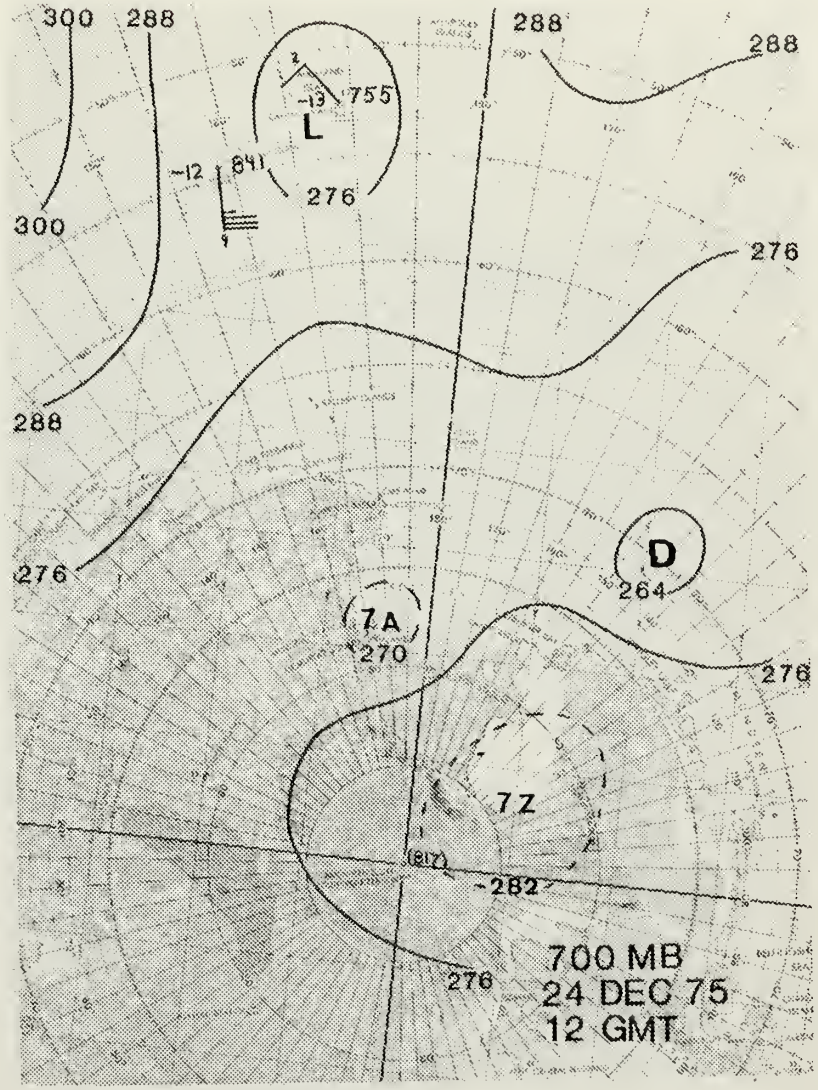


Figure 57

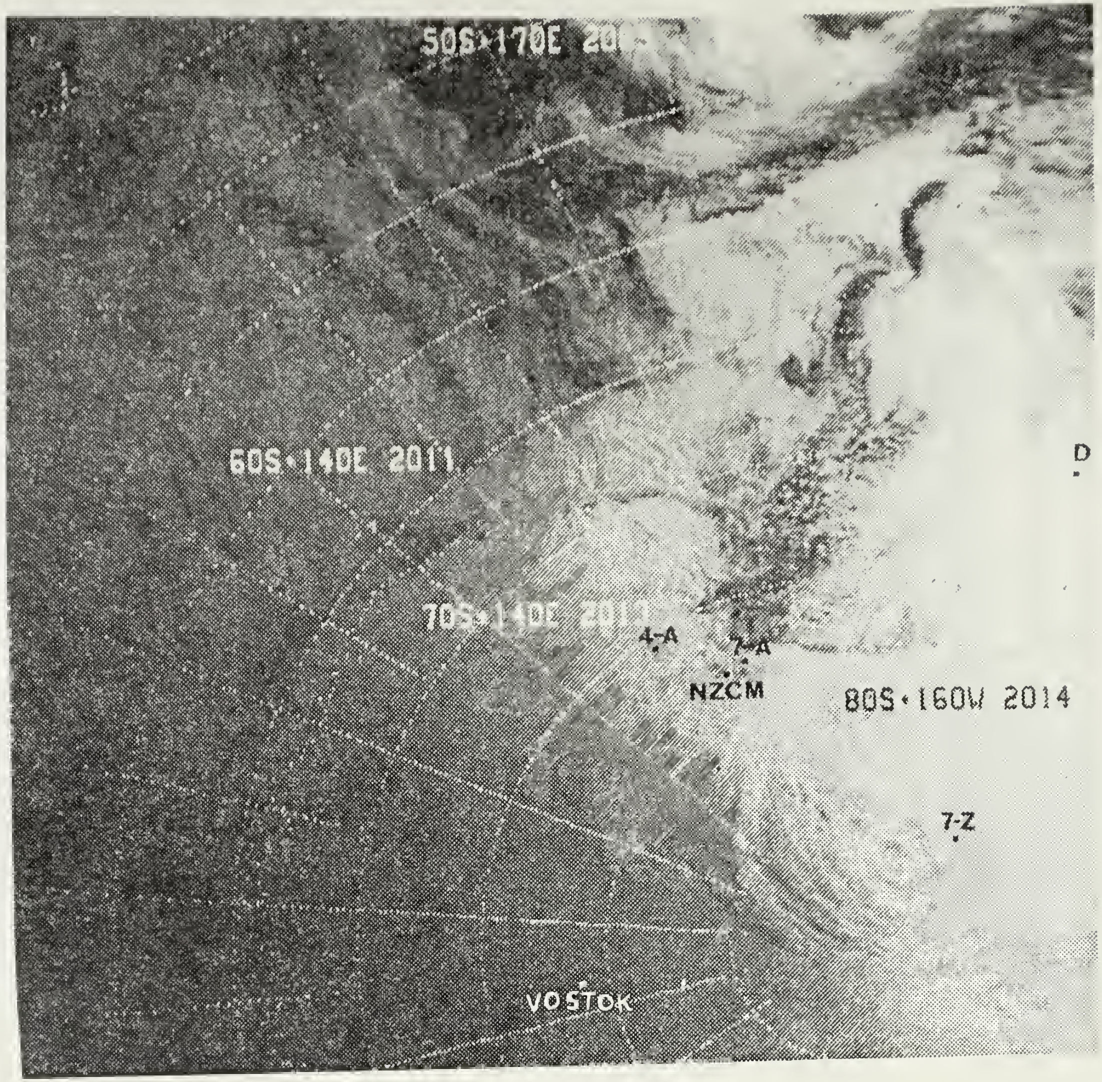


Figure 58. NOAA-4 PASS-5060 T-12 SEN-1 VIS 12/24/75 2019.

continues onto the Ross Ice Shelf and it is likely that significant snowfall is occurring throughout the ice shelf in all but the McMurdo area. Other analyses features near/on the continent are a function of time continuity.

b. Lower Troposphere (700 mb: Fig. 57)

With no RAOB sounding available from McMurdo the 700 mb analysis essentially reflects simple continuity between 00 GMT analyses of 24 and 25 December. Anticyclone 7Y has been removed as a separate entity.

7. 0000 GMT, 25 December 1975 Analyses (Figs. 59-62)

a. Upper Troposphere (400 mb: Fig. 59)

Vortex D continues to drift southwestward toward the Ross Sea area and is located by DMSP IR satellite imagery (Fig. 61) at about 71S 150W. Vortex 4-A is now centered approximately three deg lat north-northwest of McMurdo. The 35 kt northeasterly wind and $4^{\circ}C$, 24-hour temperature rise at McMurdo suggests that an air mass of lower latitude origin is now affecting the area. DMSP IR satellite imagery also depicts what appears to be two mesoscale cyclonic vortices north of McMurdo; these may be the result of a leeside development triggered by increased westerly winds. Based on the author's experience, when aircraft reports are available with similar features, it is believed unlikely that these mesoscale features extend up to the 400 mb level. The satellite imagery also depicts the ridge from Western Antarctica continuing to extend itself closer to Vostok Station. It is noted that the cloud structure of this ridge differs from conventional mid-latitude ridges, in that cloudiness is clearly evident on the downstream side of the ridge line. A possible explanation for this feature may lie in a combination of orographical lifting of saturated air along with blowing snow in connection with air advected across the ridge.

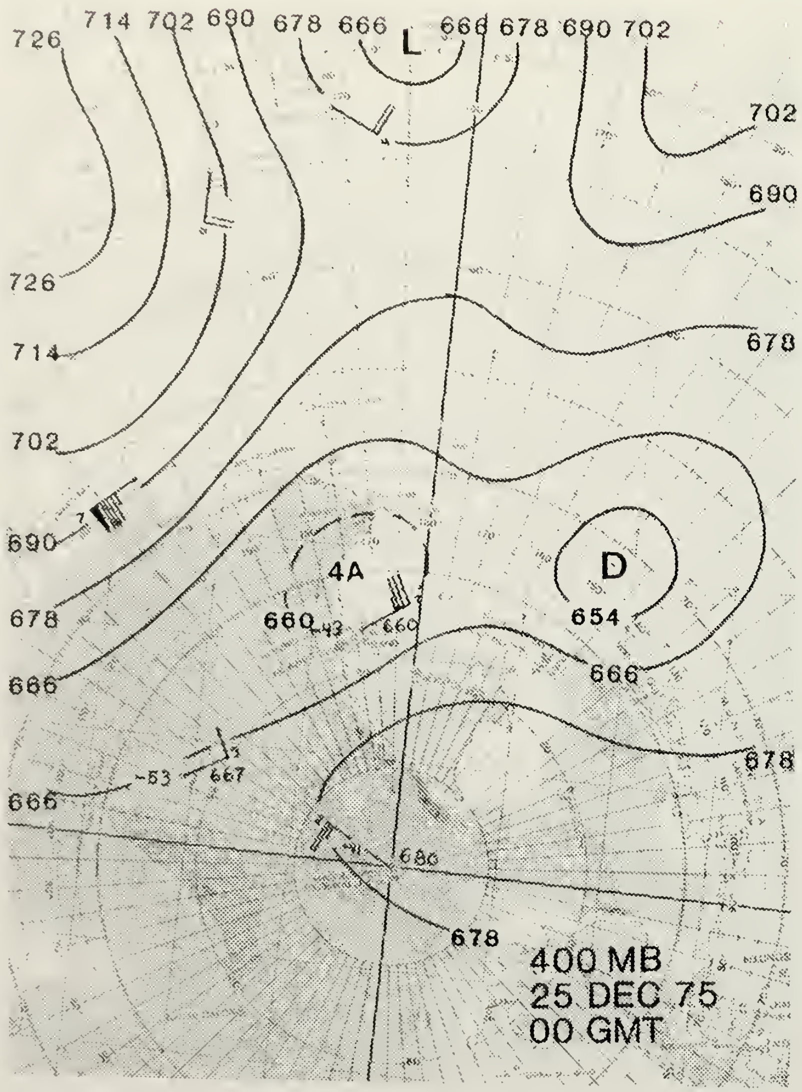


Figure 59

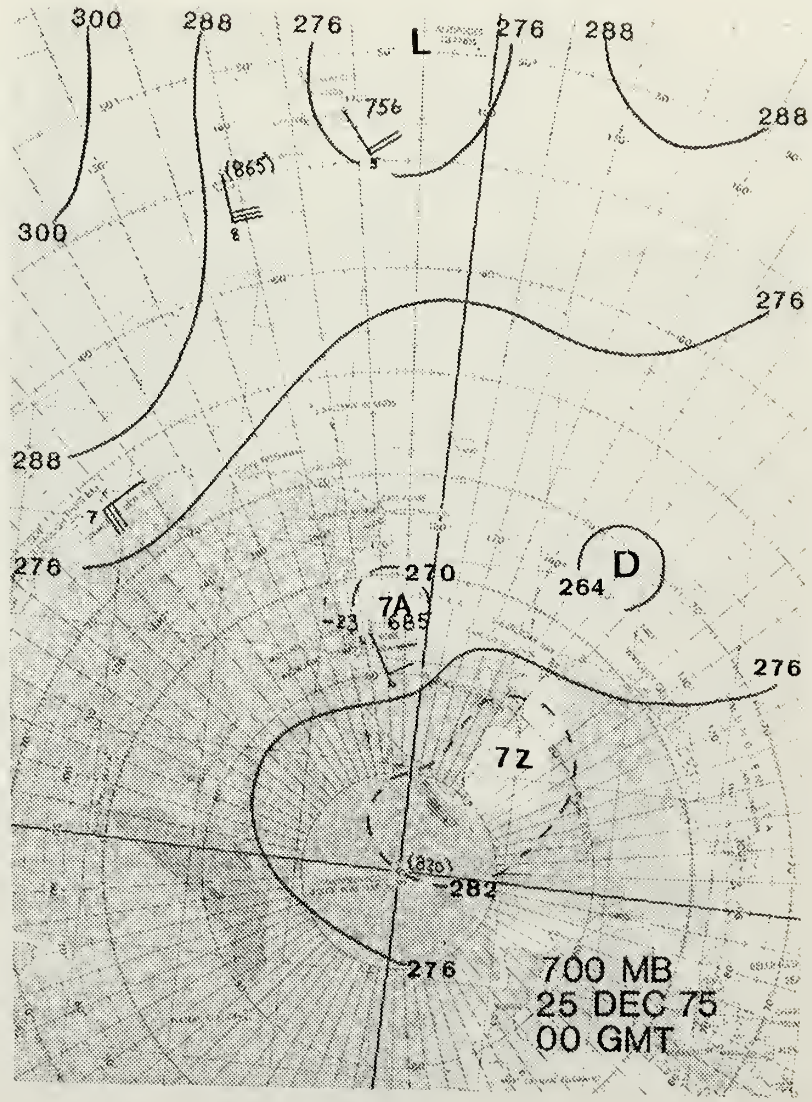


Figure 60

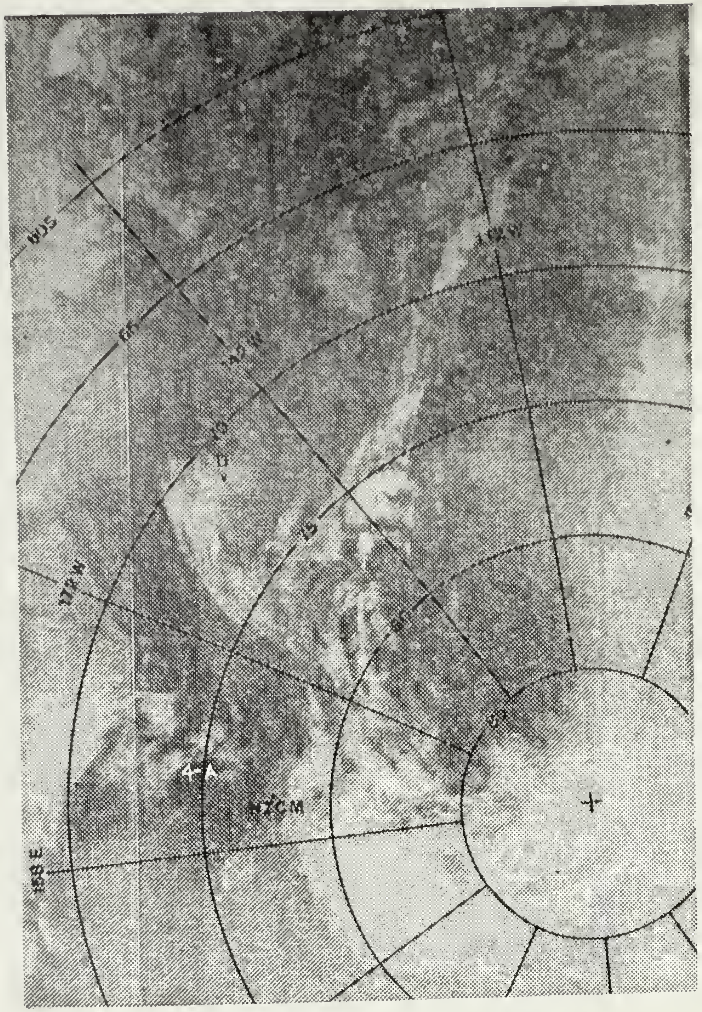


Figure 61. DMSP IR satellite observation, about 0100 GMT 25 December 1975.

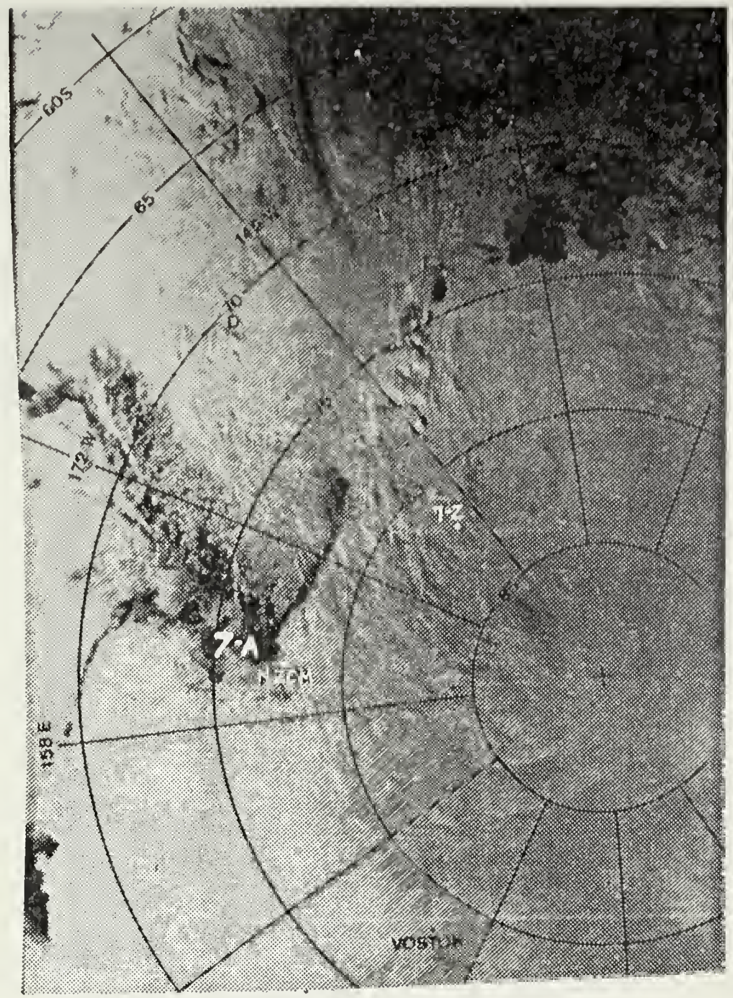


Figure 62. DMSP VIS satellite observation, about 0100 GMT 25 December 1975.

b. Lower Troposphere (700 mb: Fig. 60)

At 0300 GMT light snow was observed at McMurdo and continued for the next 26 hours. Visibility decreased to one mile at times with surface winds westerly at five to ten kts.

The vertical cross section (Fig. 66) shows the 700-mb level winds shifting to east-southeast at this time, thus indicating the arrival of part of the moist air mass over McMurdo. The DMSP visual satellite imagery (Fig. 62) shows the two small cyclonic vortices north of McMurdo. The scale of these vortices is too small for proper representation on 1:15,000,000 scale map and therefore are not represented in the analysis. Vortex D continues to drift toward the Ross Sea and is located at about 71S 150W. Anticyclonic vortex 7-Z continues to evidence itself on the visual imagery in the vicinity of 82S 148W, as indicated by anticyclonically curved cloud bands.

8. 1200 GMT, 25 December 1975 Analyses (Figs. 63-65)

a. Upper Troposphere (400 mb: Fig. 63)

Easterly winds of 35 kts at McMurdo indicates that vortex 4-A remains north of the station. NOAA visual satellite imagery (Fig. 65) no longer shows the distinct circulation previously associated with vortex D. However, there appears to be some cyclonic turning in the area of 72S 155W which is interpreted as the filling vortex D. Less moisture is apparently being advected over the eastern Ross Ice Shelf as the cloud bands are narrower than in earlier imagery. There still remains considerable cloudiness of a cumuliform nature over the Ross Ice Shelf, indicating the probability of continued inclement weather in that region. The South Pole observation showed the wind backing to grid east-southeast and an increase in temperature of 2°C over the past 24 hours, in agreement with the observed building ridge patterns observed in the satellite imagery.

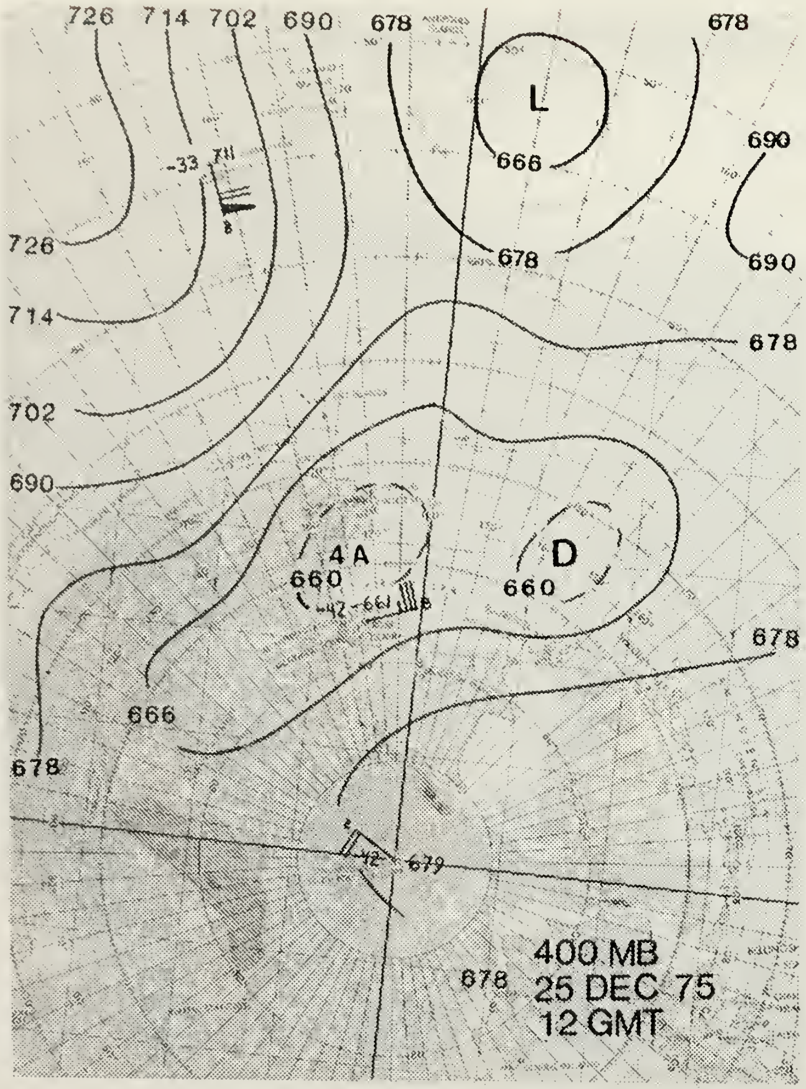


Figure 63

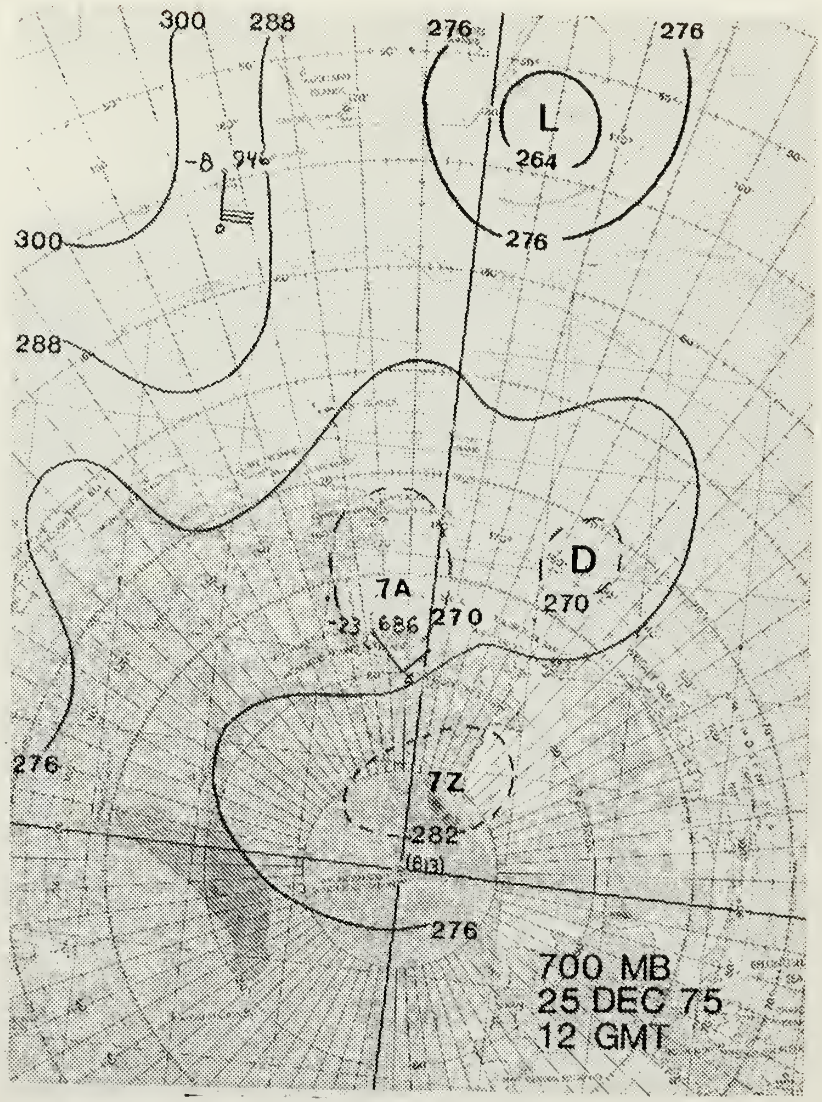


Figure 64

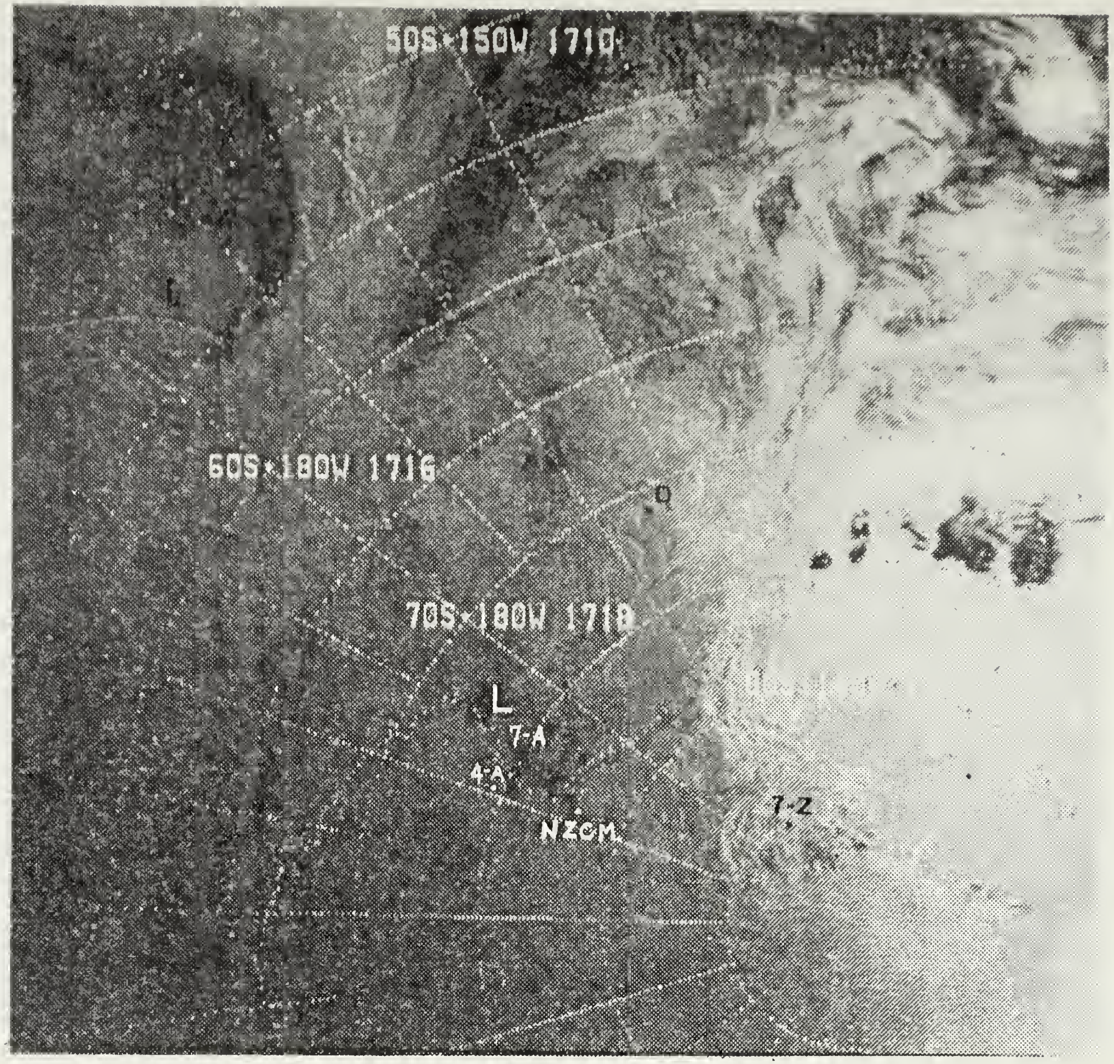


Figure 65. NOAA-4 PASS-5071 T-11 SEN-1 VIS 12/25/75 1724.

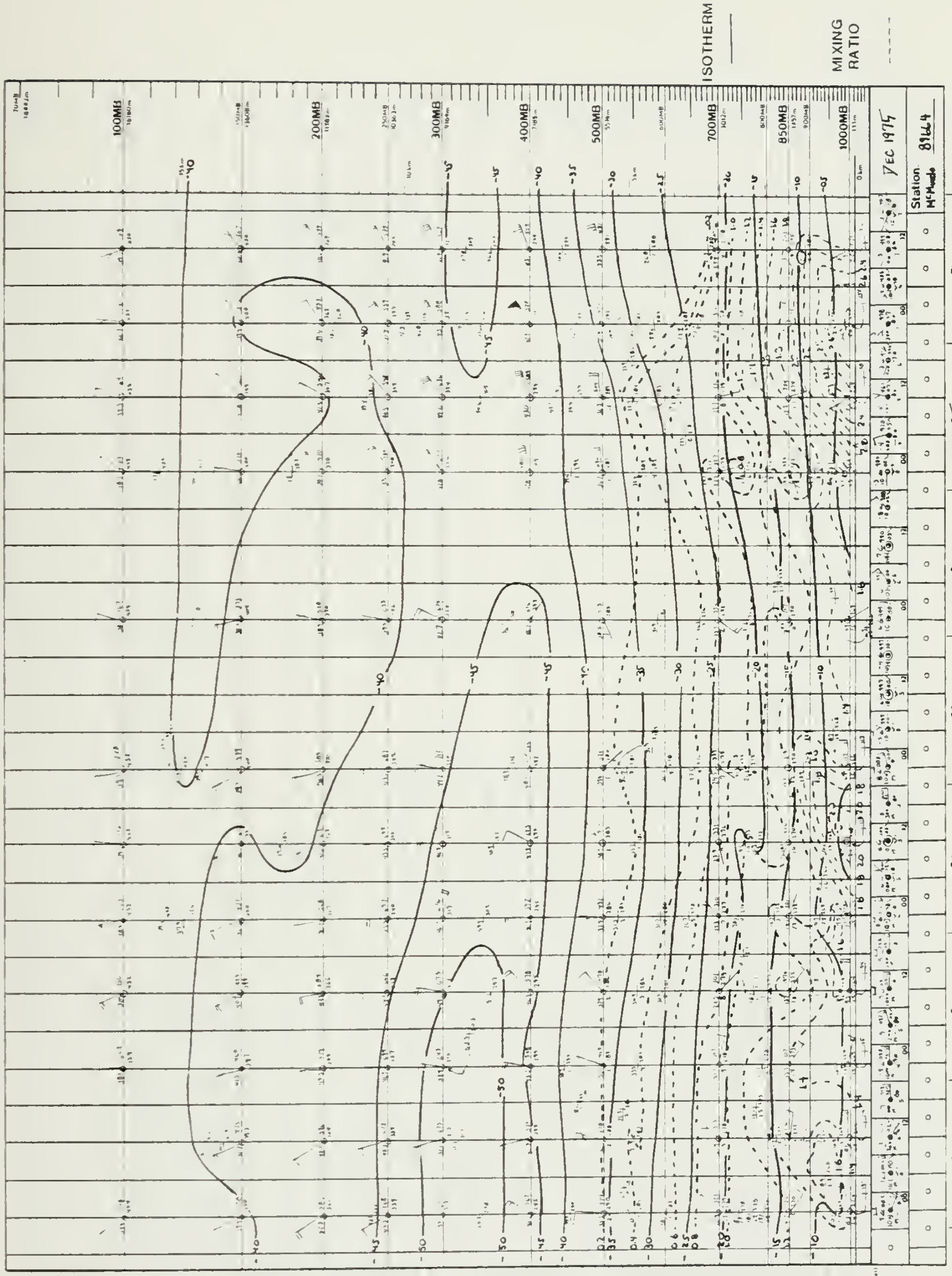


Figure 66. Vertical Time Cross-section, 20-26 December 1975.

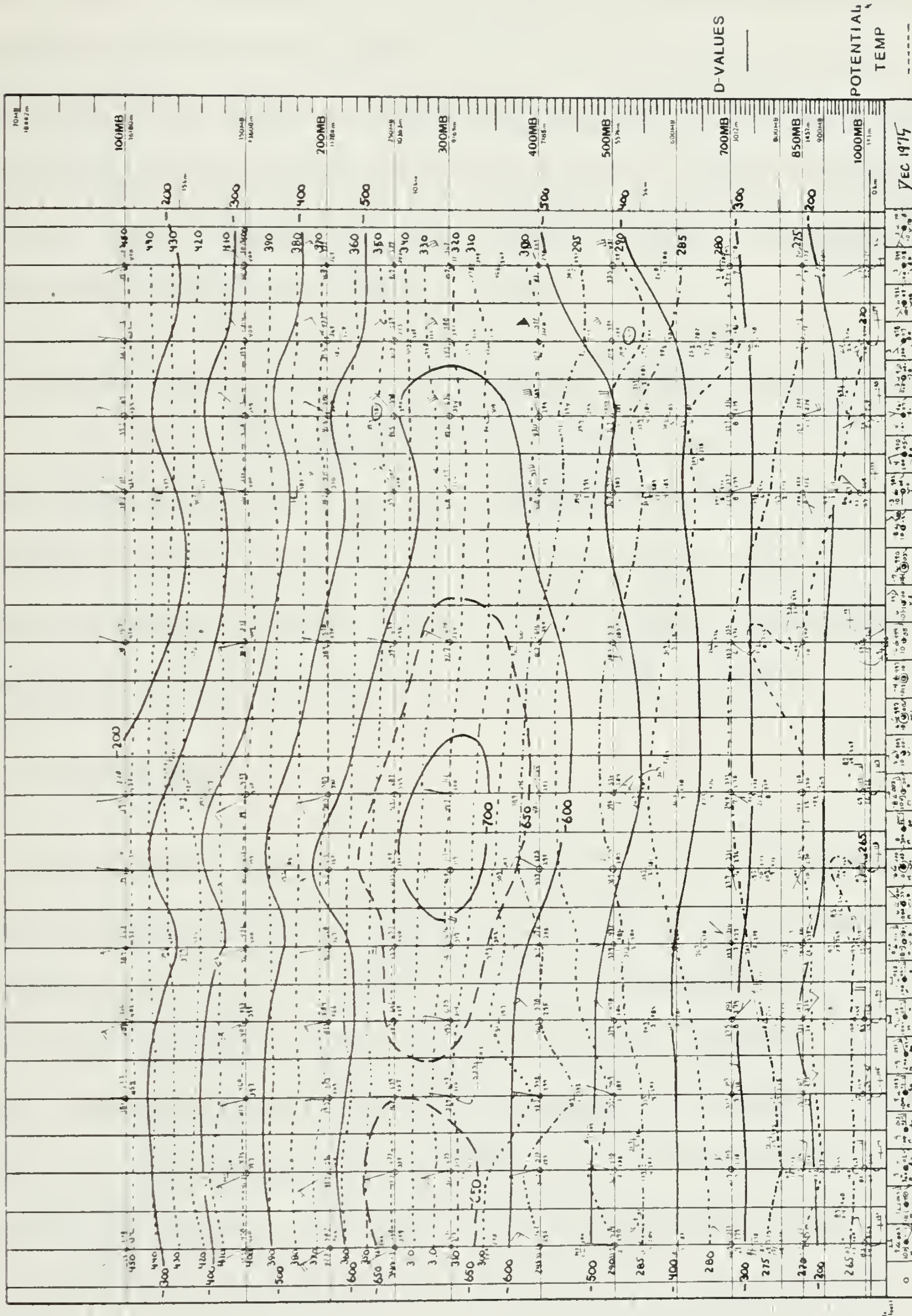


Figure 67. Vertical Time Cross-section, 20-26 December 1975.

b. Lower Troposphere (700 mb: Fig. 64)

NOAA visual satellite imagery (Fig. 65) depicts an anticyclonic vortex (7-Z) in the vicinity of 85S 160W while a cyclonic vortex appears to be located at about 73S 177E. This vortex is within the analyzed 700 mb vortex (7-A) and may be caused by a leeside effect due to the westerly winds passing over the polar plateau. Cloudiness and continuous light snow are observed through 0500 GMT, 26 December 1975 followed by light snow shower activity.

C. NUMERICALLY ANALYZED VS. SUBJECTIVELY ANALYZED CIRCULATIONS

As in the January case study the FNWC and author's 700 mb analyses are superimposed for 00 GMT 22-25 December 1977 (Fig. 68). Again, many differences between the two analyses are evident, especially in relation to the synoptic situation over western Antarctica and the Ross Ice Shelf during the period of moist air influx to high latitudes.

D. CONCLUSIONS

The synoptic weather pattern leading to the 25-26 December 1975 significant weather episode at McMurdo is that of a cyclonic vortex (D) moving southwestward from 65S 145W on 1200 GMT 22 December 1975 to 72S 155W on 1200 GMT 25 December 1975. Satellite imagery indicates this cyclone was both a moisture source and steering mechanism for moisture advection from lower latitudes to the Ross Ice Shelf. As a result of the moisture and associated warm air intrusion onto the Ross Ice Shelf, anticyclonic flow extended from West Antarctica to the Trans-Antarctic Mountain Range on 22 December to a position just to the grid west of Vostok station on 26 December. As the moisture advection and ridge building progresses, the entire Ross Ice Shelf becomes cloud bound with probable inclement weather.

Figure 68. Comparison of FNWC 700 mb analyses with those of the author. a) 22 Dec., b) 23 Dec., c) 24 Dec., d) 25 Dec. Heavy solid and dashed contours - author's analysis. Light solid, solid contours - FNWC analysis.

DMSP satellite imagery (Figs. 61 and 62) indicates that on 25 December 1975 the Ross Ice Shelf moisture has moved laterally eastward from the eastern Ross Ice Shelf, resulting in the orographic lifting of moisture in the vicinity of 76S 135-145W. With the major source of moisture cut off from the Ice Shelf, gradual clearing is then observed.

DMSP satellite imagery (Figs. 54 and 55) indicates considerable moisture just south of McMurdo on 0000 GMT 24 December 1975. Lower-level tropospheric winds (Fig. 66) are westerly at 850 mb and southwesterly at 700 mb. These westerly winds indicate that the moisture content of the air to the south is being modified by the orographical lifting to 6000 ft terrain to the south and west of McMurdo, resulting in only broken skies at McMurdo in the flow from the continent. Only when the 850 mb and 700 mb winds shifts to southeasterly at 1200 GMT 25 December 1975, does an essentially unobstructed flow of low tropospheric moisture advection exist, resulting in 26 hours of continuous snowfall beginning at 0300 GMT on 25 December 1975. It is important to note that almost simultaneous with the moisture advection and precipitation at McMurdo, the cyclonic vortex A, to the North shows signs of deepening as McMurdo sea-level pressure drops 2.1 mb between 0000 GMT and 1200 GMT on 25 December 1975.

This case study demonstrates another variation of the ridge/trough positioning and associated meridional moisture advection leading to significant weather at McMurdo. It also shows the importance of the positioning of mesoscale features such as cyclonic vortices in the steering of moisture away from or to a local area such as McMurdo.

IX. CASE STUDY OF OBSERVED KATABATIC WIND EPISODE OF 11-13 OCTOBER 1973 (Figs. 69-79)

A. INTRODUCTION

It is the objective of this case study to describe the atmospheric events leading to the glacial valley warming and associated katabatic wind flow observed in the DMSP IR satellite imagery of 13 October 1973.

Marvill and Jayaweera (1975) first described valley warming and corresponding valley winds in the Alaskan interior utilizing IR imagery form a NOAA polar orbiting satellite. This investigation treats a similar case in the Antarctic region near McMurdo and focuses on the atmospheric events preceding its occurrence. The format of the case study varies from that of the January 1976 and December 1975 cases in that only 500 mb maps are analyzed for three 24-hour intervals beginning with 0000 GMT 11 October 1973.

Vertical time cross sections inclusive of 9 through 15 October 1973 for McMurdo are presented in Figs. 78 and 79.

B. CASE STUDY ANALYSIS (00 GMT 11 October 1973 - 00 GMT 13 October 1973)

1. 0000 GMT 11 October 1973

a. 500 mb Analysis (Fig. 69)

DMSP IR satellite (Fig. 70) imagery shows southeasterly flow impinging along the Trans-Antarctic Mountain Range. Bright cloud plumes are observed along the entire length of the Trans-Antarctic Mountain Range as the moisture laden air is orographically lifted. As the orographically lifted clouds continue onto the polar plateau, a ridge line

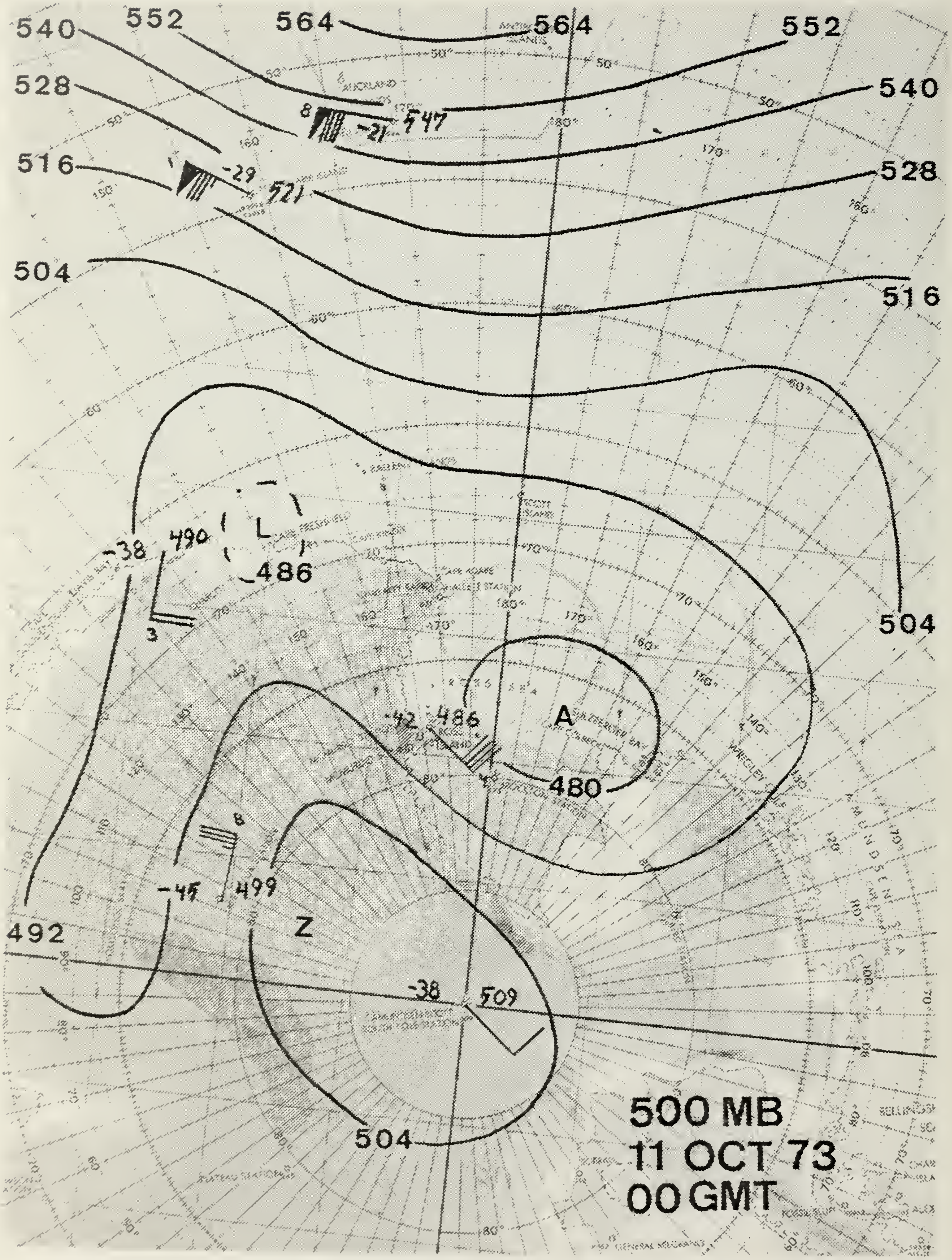


Figure 69. 500 mb analysis, 0000 GMT 11 October 1973.

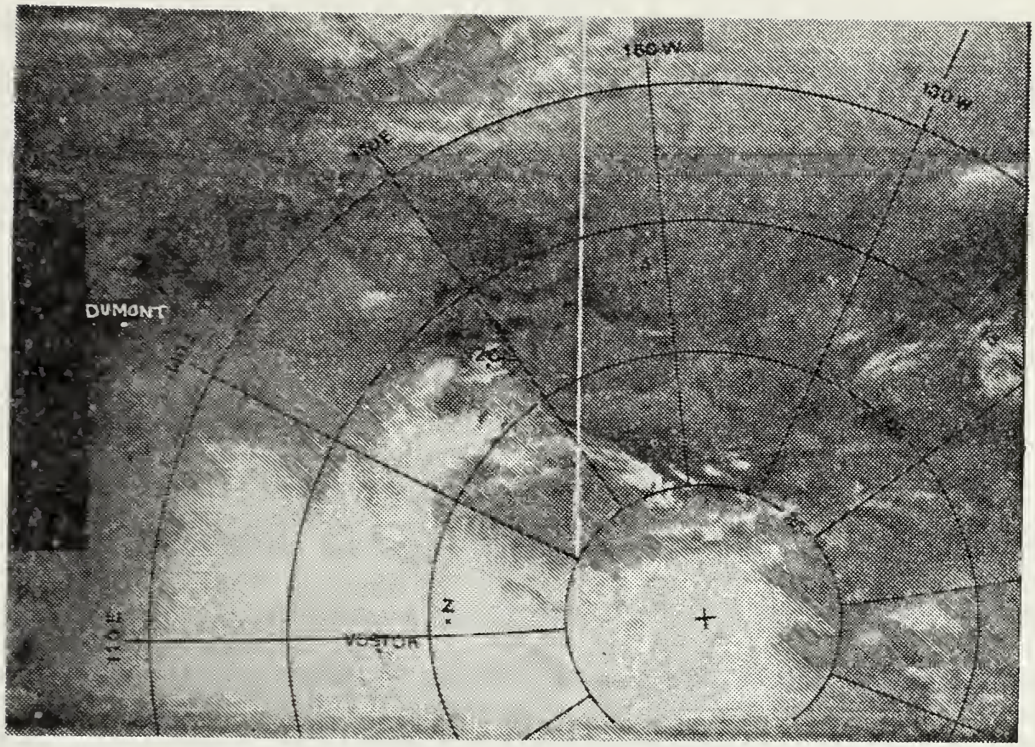


Figure 70. DMSP IR satellite observation, about 0400 GMT 11 October 1973.

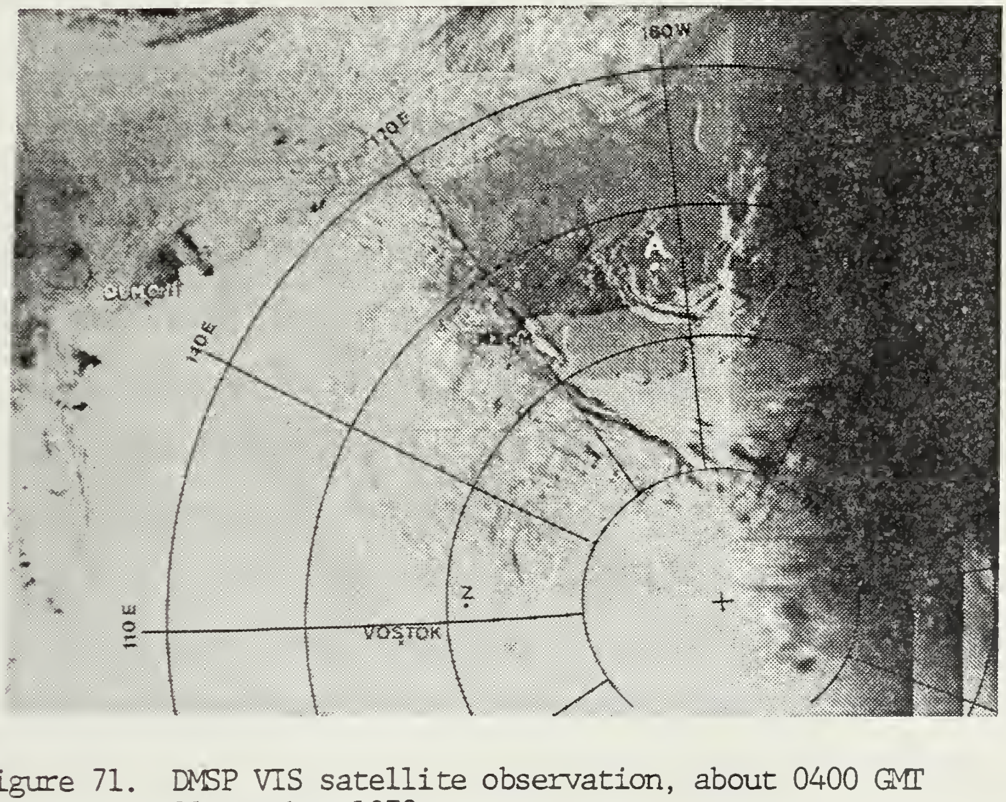


Figure 71. DMSP VIS satellite observation, about 0400 GMT 11 October 1973.

is defined by the cloud striations and anticyclonic curvature in the vicinity of 140E extending from 75S to South Pole. An east-northeasterly wind at Vostok and a southeasterly wind at McMurdo support the wind directions implied by the imagery. The anticyclonic vortex Z appears to be centered about five deg lat grid east-southeast of South Pole, using both the Pole wind and satellite imagery. Cyclonic vortex A is depicted by DMSP visual imagery (Fig. 71) in the vicinity of 77S 165W.

With the large cloud mass over the polar plateau west of McMurdo and the McMurdo surface observations reflecting restricted visibilities in snow and blowing snow of one mile or less in each of the seven previous days it can be assumed that considerable snowfall has occurred along the Trans-Antarctic Mountain Range. It is of interest to note in the visual imagery the tongue of clear air approaching the Trans-Antarctic Mountain Range in the area poleward of 80S.

2. <u>0000 GMT 12 October 1973</u>

a. 500 mb Analysis (Fig. 72)

DMSP IR satellite imagery (Fig. 73) shows clouds impinging on the Royal Society Mountain Range and other elevated topographical features south of McMurdo. The bright returns from cloud plumes appear to be oriented along a south-southeasterly direction, agreeing well with the lower tropospheric winds (Fig. 78) from the 0000 GMT McMurdo sounding.

Anticyclonic vortex Z has moved to a position approximately 6 deg lat grid southeast of South Pole. Anticyclonic vortex Y appears to have formed near Vostok Station as indicated by a 24-hour 90 gpm, and $3^{\circ}C$ rises and anticyclonic cloud striations in the DMSP visual satellite imagery (Fig. 74). McMurdo has experienced a tightening contour gradient as evidenced by a 25 kt wind increase to 65 kt and 30 gpm rise in height. Cyclonic vortex A has moved westward and is located at about 75S 174W.

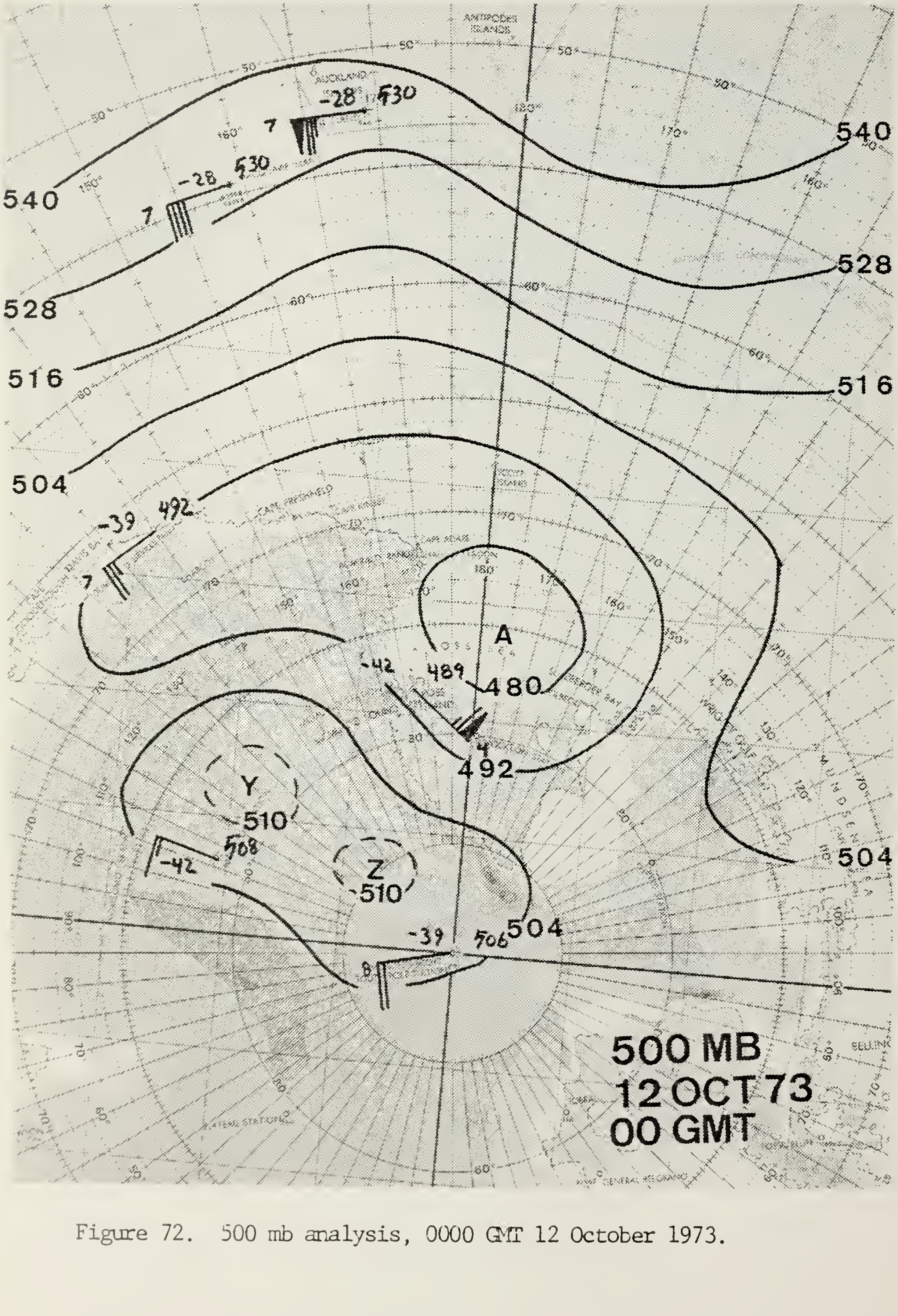


Figure 72. 500 mb analysis, 0000 GMT 12 October 1973.

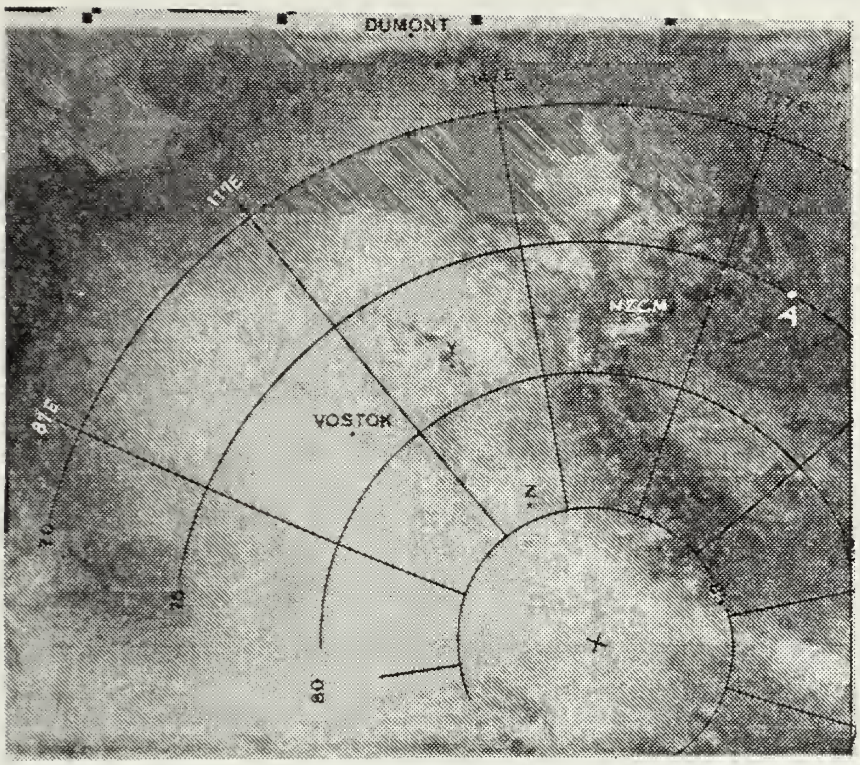


Figure 73. DMSP IR satellite observation, about 0730 GMT 12 October 1973.

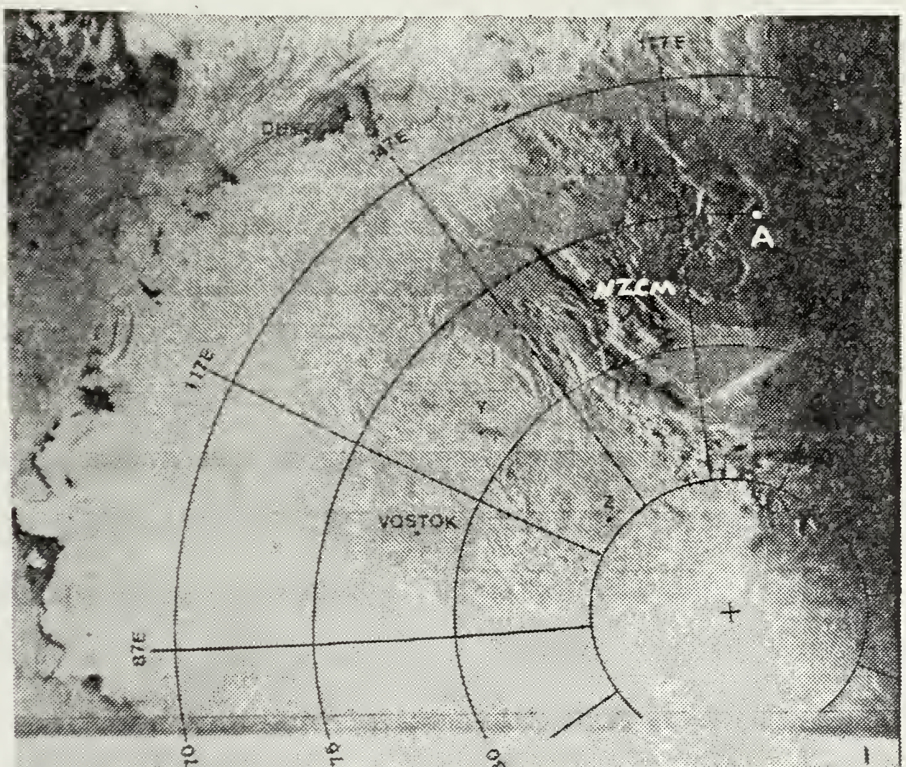


Figure 74. DMSP VIS satellite observation, about 0730 GMT 12 October 1973.

DMSP visual satellite imagery shows clearing skies in the vicinity of the southernmost portion of the Trans-Antarctic Mountain Range. This is an indication of a shift in wind to a more southerly component in that region. South Pole's 20 kt grid east-northeast wind supports this assumption.

3. <u>0000 GMT 13 October 1973</u>

a. 500 mb Analysis (Fig. 75)

During the past 24-hour period the entire length of the Trans-Antarctic Mountain Range south of 77S has become cloud free, indicating predominant southerly flow. The South Pole 500 mb observation shows a 24-hour 100 gpm and $3^{o}C$ temperature drop indicating anticyclonic vortex Z has moved away from the station or weakened. DMSP satellite visual imagery (Fig. 77) shows anticyclonic curvatures associated with the anticyclonic vortex Y at a position of about 5 deg lat west of McMurdo. A polar cyclonic vortex appears to be approaching South Pole from the grid northwest. As indicated by DMSP IR and visual satellite imagery (Figs. 76 and 77), cyclonic vortex A has drifted slightly westward. The 24-hour 70 gpm height rise and 15 kt decrease in wind speed at McMurdo infer that vortex A is filling.

IR imagery shows what is interpreted as glacial valley or katabatic wind flow along the glacial valleys of the Trans-Antarctic Mountain Range south of 78S. Dark, relatively warm streams of air, originating along the slopes of glacial valleys are observed curving anticyclonically back toward the polar plateau. As the katabatic streams impinge upon the Royal Society Mountains and other elevated topographical features south of McMurdo, the air is orographically lifted and the formation of cloud plumes result. The most intense dark stream originates

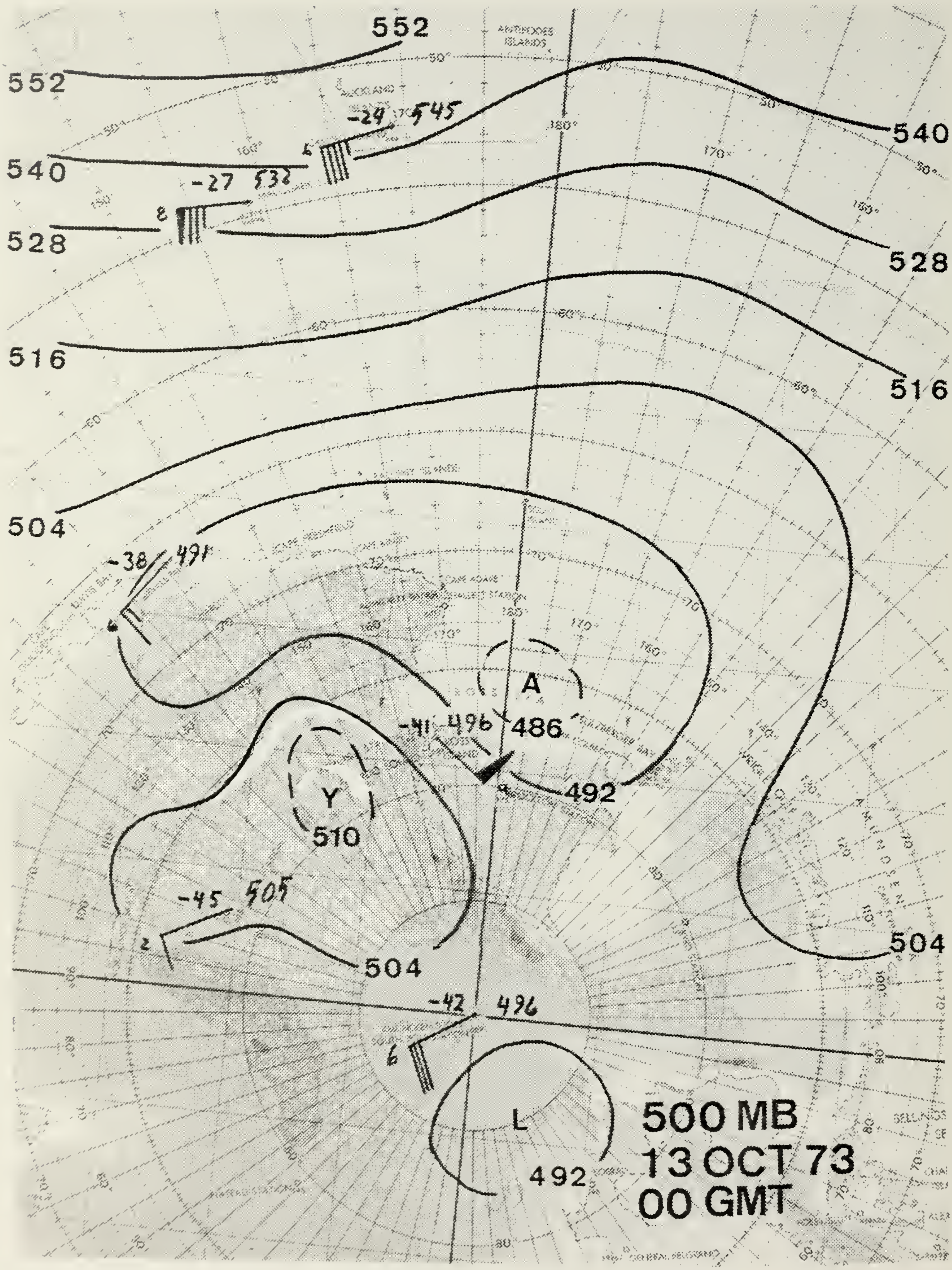


Figure 75. 500 mb analysis, 0000 GMT 13 October 1973.

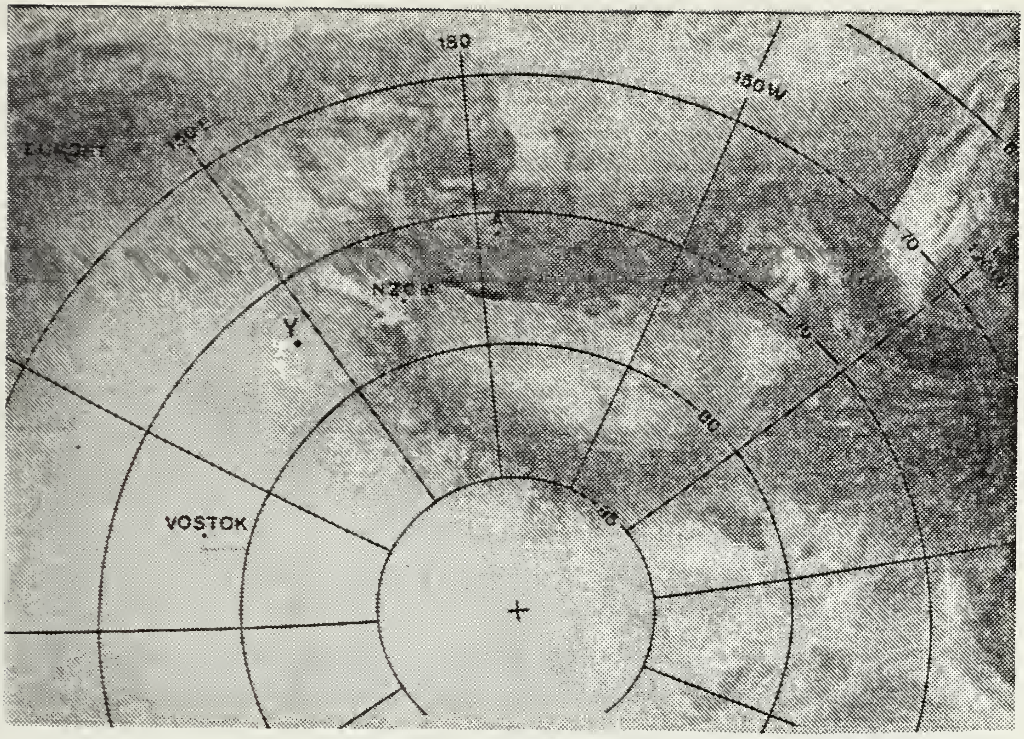


Figure 76. DMSP IR satellite observation, about 0530 GMT 13 October 1973.

Figure 77. DMSP VIS satellite observation, about 0530 GMT 13 October 1973.

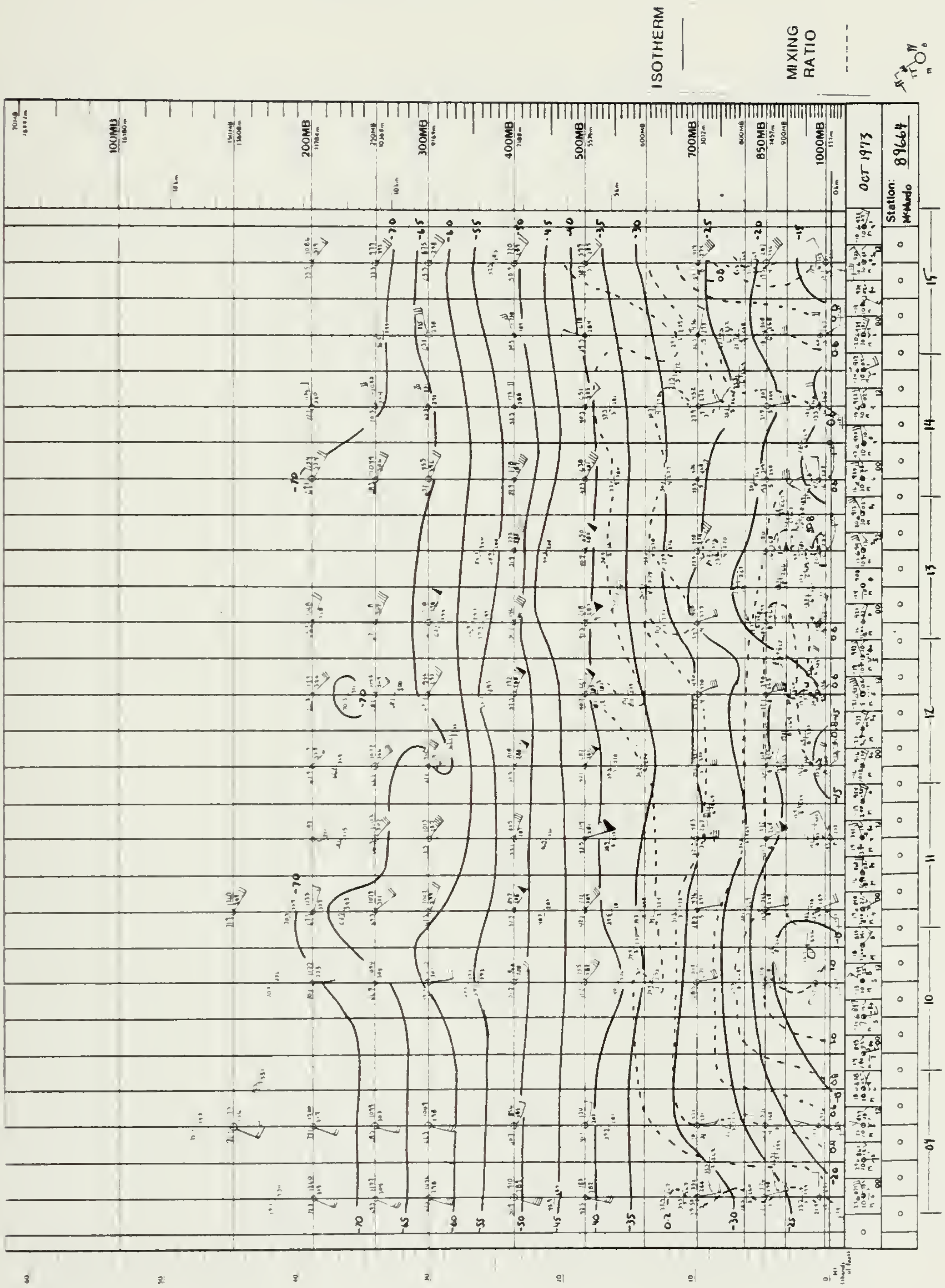


Figure 78. Vertical Time Cross-section, 9-15 October 1973.

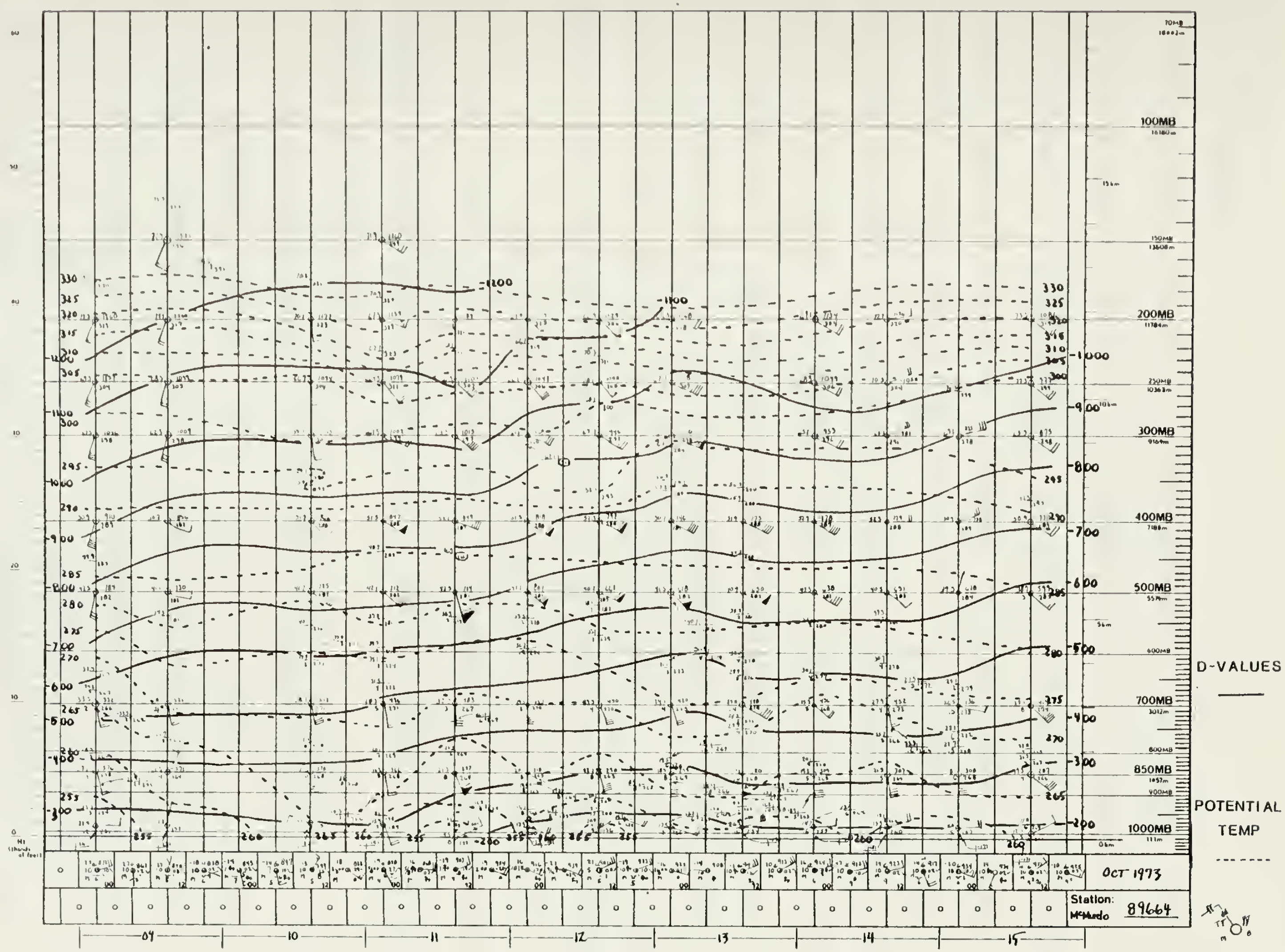


Figure 79. Vertical Time Cross-section, 9-15 October 1973.

from the Byrd Glacier which comes onto the Ross Ice Shelf between 80 and 81S. Another dark stream originates from the Nimrod Glacier which intersects the Ross Ice Shelf between 82 and 83S.

C. CONCLUSIONS

The probable atmospheric events leading to the observed glacial katabatic flow are as follows: 1) A large cloud mass of moist air intrusion originating from lower latitudes is observed over the polar plateau between McMurdo and Vostok on 11 October 1973, 2) Concomitant with the orographic lifting of this mass from the low elevation (2-300 ft msl) of the Ross Ice Shelf to the high elevation of the polar plateau (7-8000 ft msl) a large amount of snowfall occurs, 3) On 12 October 1973 the complex anticyclonic circulation over the polar plateau is in the process of extending northward between Vostok and McMurdo, 4) On 13 October 1973 an anticyclonic vortex is centered approximately 5 deg of lat west of McMurdo and a cyclonic vortex about 4 deg of lat northeast of McMurdo.

This is a case whereby the juxtaposition of a cyclone to the northeast and an anticyclone to the west of McMurdo is such as to impose a regional pressure gradient and wind to cause katabatic flow in the vicinity of Byrd and Nimrod Glaciers.

With the ample supply of loose snow that had fallen a few days earlier, a vast low-level moisture transfer appears to occur, originating from the polar plateau as blowing snow, and then being orographically lifted by the Royal Society Mountains, thus forming cloud plumes which extend over the polar plateau once again. Comparison of DMSP visual and IR satellite imagery shows the region where orographically lifted clouds are formed from apparently clear sky conditions noted on the visual imagery.

A possible explanation to the glacial valley warming observed in the IR imagery may be that the layer of blowing snow partakes of the adiabatic warming in the downslope motion and hence appears darker than the surrounding and less disturbed snow covered mountain areas.

X. CONCLUSIONS AND RECOMMENDATIONS

The principal objective of this study was to identify the synoptic and associated mesoscale weather patterns leading to significant weather days at McMurdo Station, Antarctica. Through the utilization of DMSP and NOAA satellite imagery in supplementing conventional and aircraft data, synoptic and mesoscale patterns preceding and during significant weather at McMurdo are identified. Meridional moisture advection from lower to higher latitudes associated with building and/or transitory ridges are identified in three case studies from recent years. The DMSP imagery in each case study exhibited sufficient resolution to enable the observation of movement and areal extent of the associated moisture.

Mesoscale features such as cyclonic and anticyclonic vortices were shown to play an important role as triggering or blocking mechanisms in connection with significant weather at McMurdo. Glacial valley warming/katabatic winds were observed on DMSP infrared satellite imagery.

The interrelationship of conventional data and satellite imagery were demonstrated throughout the case studies. Lower level tropospheric ground truth observations tend to support quite well observed imagery features such as orographically lifted cloud plumes and striations.

FNWC 700 mb analyses were compared to the author's analyses for the January 1976 and December 1975 case studies. The problems of numerical analysis without aid of satellite data over essentially dataless ice cap regions were demonstrated.

The following recommendations are offered for future studies and action:

1) Investigate all significant weather days from recent years, utilizing conventional data and satellite imagery as practical, to qualitatively determine the gross synoptic scale positions of ridges and troughs associated with such days.

2) Research man-machine mix methodology to enhance the accuracy of numerical analyses, utilizing satellite imagery input.

3) Investigate through additional case studies the importance of mesoscale features in cyclogenesis over the Ross Sea area.

4) Establish a national archive for unofficial observations from research field parties and Williams field (McMurdo airfield) observations to aid in mesoscale analysis over the Ross Ice Shelf.area.

5) As demonstrated in this study, DMSP satellite imagery proved superior to NOAA SR imagery in identification of weather systems over the polar ice cap, therefore investigate the possibility of providing the Naval Support Force, Antarctic meteorologists and/or Fleet Weather Facility, Suitland satellite analysts with real-time DMSP quality satellite imagery.

6) Investigate the dynamics of the glacial valley warming/katabatic type flow as observed in the October 1973 case study, perhaps employing strategically located automatic weather stations or specially configurated aircraft observation platforms, as well as dropsondes.

APPENDIX A

Significant Weather Days at McMurdo
September 1971-January 1977

Legend:

F = Fog		--	= very light
IF = Ice Fog		-	= light
S = Snow		No symbol	= moderate
SG = Snow Grains		+	= heavy
BS = Blowing Snow			

Day	Month	Yr.	Lowest Visibility(mi)	Obstructions to Visibility
19	Sept	71	1/8	S BS
25	Sept	71	1/4	S BS
14	Oct	71	0	S BS
15	Oct	71	1/16	S BS
16	Oct	71	1/8	S BS
17	Oct	71	1/4	S BS
23	Oct	71	3/4	S-
25	Oct	71	1/2	S-
26	Oct	71	1/2	S--, IF, BS
16	Nov	71	1	S-
23	Nov	71	1	S--, BS
27	Nov	71	1/8	IF
28	Nov	71	1/8	IF
08	Dec	71	1/2	S
09	Dec	71	1/2	S
10	Dec	71	1/2	S
13	Dec	71	1/2	F
16	Dec	71	1/4	S+
19	Dec	71	1	S-
21	Dec	71	1	S-
22	Dec	71	3/4	S-
23	Dec	71	1/16	S BS
06	Jan	72	1	S-- F
24	Jan	72	3/4	S- BS
25	Jan	72	3/4	S- BS
29	Jan	72	1/2	IF BS
11	Feb	72	5/8	S-
13	Feb	72	1	S-
15	Feb	72	3/4	S
16	Feb	72	7/16	S BS
17	Feb	72	3/8	S BS
28	Feb	72	1	S- BS
03	Mar	72	1/2	S- BS
09	Mar	72	1/2	S- BS
10	Mar	72	5/8	S- BS
15	Sept	72	1/4	BS
04	Oct	72	1/16	S- BS

05	Oct	72	1/4	S- BS
06	Oct	72	1/4	S- BS
09	Oct	72	1	S-
10	Oct	72	1	BS
14	Oct	72	0	S- BS
20	Oct	72	1/2	S- BS
27	Oct	72	1/4	S-- BS
28	Oct	72	0	S- BS
29	Oct	72	1/16	BS
01	Nov	72	1/4	BS
09	Nov	72	1/2	S- BS
11	Nov	72	1/2	S-- IF
12	Nov	72	1	BS
20	Nov	72	1	S- BS
21	Nov	72	1	S- BS
25	Nov	72	7/16	S-
26	Nov	72	1/2	BS
16	Dec	72	1/2	S
10	Jan	73	1/4	S+
11	Jan	73	5/8	S-
16	Jan	73	1/8	F
17	Jan	73	7/8	F
07	Feb	73	1	S-
08	Feb	73	1	S-
10	Feb	73	3/4	S- BS
11	Feb	73	1/8	S+ BS
15	Feb	73	1/2	S
16	Feb	73	3/4	S- BS
18	Feb	73	3/8	BS
07	Mar	73	1	S- BS
09	Mar	73	3/8	IF
11	Mar	73	1/16	BS
12	Mar	73	1/8	S- BS
13	Mar	73	1/2	BS
15	Sept	73	5/8	IF
17	Sept	73	5/8	S-
18	Sept	73	0	S- BS
19	Sept	73	5/8	BS
20	Sept	73	5/8	S-
21	Sept	73	3/8	S- BS
30	Sept	73	3/8	BS
01	Oct	73	1	BS
02	Oct	73	5/8	S- BS
04	Oct	73	5/8	S-
05	Oct	73	1/8	S BS
08	Oct	73	3/8	BS
10	Oct	73	1	BS
11	Oct	73	5/8	S- BS
12	Oct	73	9/16	BS
13	Oct	73	5/8	S-
16	Oct	73	1/4	S-- BS
17	Oct	73	3/4	S-

18	Oct	73	3/4	S- BS
19	Oct	73	1/2	BS
20	Oct	73	0	S- BS
21	Oct	73	1/4	BS
22	Oct	73	5/8	BS
24	Oct	73	1/2	S+
26	Oct	73	1/2	S BS
27	Oct	73	5/8	S- BS
03	Nov	73	1/8	S BS
04	Nov	73	1/4	BS
13	Nov	73	5/8	BS
14	Nov	73	1/4	S- BS
15	Nov	73	1/4	S+
16	Nov	73	3/16	BS
18	Nov	73	3/4	S-
19	Nov	73	1	S
21	Nov	73	1	S-
24	Nov	73	1	S-
11	Dec	73	1	S-
17	Dec	73	1	S-
18	Dec	73	1/2	S
19	Dec	73	1	S-
25	Dec	73	1	S
29	Jan	74	9/16	S
17	Feb	74	1/16	S+
19	Feb	74	1	S-
20	Feb	74	5/16	S+
01	Mar	74	1/2	BS
03	Mar	74	1/16	S+ BS
05	Mar	74	1/2	S IF
06	Mar	74	1/16	S+ BS
07	Mar	74	1/2	BS
17	Sept	74	1/2	IF
18	Sept	74	1/4	IF
22	Sept	74	1/2	S-- IF
23	Sept	74	1/4	S- BS
25	Sept	74	5/8	BS
05	Oct	74	3/8	S- BS
23	Oct	74	3/4	BS
24	Oct	74	1/8	BS
26	Oct	74	5/8	BS
27	Oct	74	7/8	BS
28	Oct	74	5/16	S- BS
01	Nov	74	3/4	S-
02	Nov	74	1	S- BS
19	Nov	74	1/2	S
20	Nov	74	5/8	S-
30	Nov	74	5/8	S-
19	Dec	74	1/2	F
20	Dec	74	1/8	S-- F
25	Dec	74	1	S-
04	Jan	75	1/2	S-
05	Jan	75	15/16	S-

21	Jan	75	3/4	S-
02	Feb	75	3/4	S-
16	Feb	75	3/4	S-
18	Feb	75	9/16	S
19	Feb	75	3/4	S-
03	Mar	75	1/2	S
11	Mar	75	5/16	IF
17	Sept	75	1/4	S- BS
19	Sept	75	1	BS
25	Sept	75	1/4	BS
26	Sept	75	1/8	BS
28	Sept	75	1/4	BS
06	Oct	75	3/4	S BS
19	Oct	75	3/4	S- BS
20	Oct	75	5/8	S- BS
09	Nov	75	1/2	BS
11	Nov	75	1/2	S-
02	Dec	75	3/4	S-
03	Dec	75	1/2	S
06	Dec	75	1/2	F
21	Dec	75	1	S-
25	Dec	75	1	S-
11	Jan	76	5/8	S- BS
22	Feb	76	1/2	S
26	Feb	76	3/4	S- BS
			March 76 data missing	
01	Sept	76	1	BS
05	Sept	76	1/8	S- BS
06	Sept	76	1/8	S- BS
14	Sept	76	1/16	S- BS
15	Sept	76	3/8	S- BS
16	Sept	76	3/4	S- BS
20	Sept	76	7/16	S- BS
04	Oct	76	1/2	F
20	Oct	76	1	BS
05	Nov	76	0	S BS
06	Nov	76	1/4	S BS
14	Nov	76	1	S-
15	Nov	76	0	BS
17	Nov	76	1/16	S BS
28	Nov	76	1	S- BS
17	Dec	76	1/4	F
19	Dec	76	3/4	S- F
24	Dec	76	3/4	S- BS
04	Jan	77	5/8	S
07	Jan	77	1/4	S BS
08	Jan	77	1/2	SG SBS
09	Jan	77	1	S- F

REFERENCES

1. Bittner, F. W., 1970: "Guide for Interpretation of Satellite Photography and Nephanalyses, Project FAMOS Research Report (4-67)" Walter A. Bohan Company, Park Ridge, Illinois, August 1967.

2. Marvill, S., and K.O.L.F. Jayaweera, 1975: "Investigations of Strong Valley Winds in Alaska Using Satellite Infrared Imagery," Monthly Weather Review, 103, 1129-36.

3. Naval Weather Service Command, 1975: "U. S. Naval Weather Service Numerical Environmental Products Manual, NAVAIR 50-1G-522", Department of the Navy, Washington, D. C.

4. Renard, R. J., 1975: "Report of Polar Meteorology Workshop," Desert Research Institute Technical Report, Series P No. 18, 88-90.

5. Streten, N. A. and A. J. Troup, 1973: "A Synoptic Climatology of Satellite Observed Cloud Vortices over the Southern Hemisphere," Quarterly Journal Royal Meteorological Society, 99, 56-72.

6. Taljaard, J. J. et al, 1969: "Climate of the Upper Air, Part 1-Southern Hemisphere, Volume 1," NAVAIR 50-1C-55, National Weather Records Center, Environmental Data Service, ESSA, Asheville, N. C.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Library, Code 0142 Naval Postgraduate School Monterey, California 93940	2
2.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
3.	Professor Robert J. Renard, 63Rd Department of Meteorology Naval Postgraduate School Monterey, California 93940	6
4.	Lt. Raymond H. Godin 103 Harrison Ave. Woonsocket, Rhode Island 02895	2
5.	Mr. Robert Fett Naval Environmental Prediction Research Facility Monterey, California 93940	1
6.	Mr. Kevin Rabe Naval Environmental Prediction Research Facility Monterey, California 93940	1
7.	Meteorological Officer Naval Support Force Antarctica Construction Battalion Center Port Hueneme, California 93043	3
8.	Lt. Ronald E. Englebretson Naval Environmental Prediction Research Facility Monterey, California 93940	1
9.	LCDR M. J. Nemcosky 2253 Corbett Avenue Norfolk, Virginia 23518	1
10.	Commanding Officer Fleet Numerical Weather Central Monterey, California 93940	1
11.	Commanding Officer Naval Environmental Prediction Research Facility Monterey, California 93940	1

12. Commanding Officer 1
Fleet Weather Facility
FOB #4
Suitland, Maryland 20373

13. Professor W. Denner, 68Dw 1
Department of Oceanography
Naval Postgraduate School
Monterey, California 93940

14. Commanding Officer 1
Air Force Global Weather Central
Offutt Air Force Base
Omaha, Nebraska 68113

15. Director, Naval Oceanography and Meteorology 1
National Space Technology Laboratory
Bay St. Louis, Mississippi 39520

16. Dr. Glenn A. Flittner 1
Code W-16 National Weather Service
Silver Spring, Maryland 20910

171782
Thesis
G5234 Godin
c.1
An investigation of synoptic and associated mesoscale patterns leading to significant weather days at McMurdo Station, Antarctica.